ORIGINAL ARTICLE

# Detection of Root Caries Using Laser-Based Detection Device - DIAGNOdent

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**ABSTRACT**

**Introduction:** Dental care for older population is becoming a matter of concern within the National health services (NHS) United Kingdom (UK) due to increasing life expectancy of older people and retention of their natural teeth. The aim of study was to relate the International Caries Detection and Assessment System (ICDAS) scores with severity index in order to detect root caries and DIAGNOdent readings, at an early stage, to manage these lesions non-invasively.

**Methods:** Fresh 95 extracted teeth were collected from Oral Surgery and Dental Emergency Department at Barts and the London, Queen Mary University of London. In this in vitro study, 19 out of 95 teeth had root caries. Prior to recording the readings, extracted teeth were cleaned and polished. Each lesion underwent clinical examination. To detect root caries DIAGNOdent readings (ICDAS), severity index were obtained. Pearson's correlation coefficients tests were applied.

**Results:** The correlation between cavitation and ICDAS scores shows the significant value of 0.01. The DIAGNOdent reading with momentum and peak values was 45.37 with standard deviation of 32.16 and for peak with the mean value of 49.79 and 31.72 of standard deviation. Regarding, readings of DIAGNOdent and severity index establishment of correlation was difficult to establish. The reason was score of severity index regarding specimen no.1 is 3.3 was illustrative of lesion that is leathery.

**Conclusion:** The DIAGNOdent readings system did not support the detection of root caries. However, the severity index scoring system is in need of greater categories regarding caries of the root.

**Keywords:** Root Caries; Association; Diagnosis; DIAGNOdent.

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## INTRODUCTION

Dental care for older population is becoming an issue within the National health services N.H.S due to increasing life expectancy of older people and retention of their natural teeth. Root caries is the commonest dental caries within this population. Studies carried out for identification of risk factors involved in development of root caries in older population. These include; periodontal attachment loss, past history of dental caries, deteriorating cognitive status, poly pharmacy, poor socio-economic background, micro-organisms related to root caries, as well as not availing services[1]. The prevalence of root caries was recorded as 36-67% in several studies[2,3]. Another study, revealed the 88.4% of root caries prevalence in the age range of individuals 55 years or more[4]. It is noted that if the age of individual is high then they are more vulnerable and susceptible to root caries. Irregular attendance and high sugar intake are especially reported to increase the risk of root caries amongst older population[5,6]. A debate has been there repetitively regarding the surfaces of the root caries. Raja et al. reported that interproximal or labial/buccal surfaces are mainly affected. Subsequently, the most

susceptible surfaces for caries of the root are the "lingual" "surfaces"[7].

The aetiology of root caries has many factors involved. The microbiological factor is the most significant factor amongst all other factors. Microbiological population within root caries demonstrated diversity when compared to previous studies. Actinomyces species as well as Lactobacillus species showed significant responsibility[7]. Marsh et al previously demonstrated microorganisms associated with active and progressive root carious lesions[8]. The risk factors related to root caries in older people are xerostomia, chronic periodontitis, radiotherapy for management of head and neck cancers, diet, Type 2 Diabetes mellitus, compromised manual dexterity due to arthritis, Parkinson's disease, stroke, cognitive deficiencies due to depression, dementia, Sjogren's syndrome, poor plaque control, previous experience of root caries, use of removable partial dentures[5,9-11].

There are also two types of root caries; primary and secondary root caries. Dental caries which initiates on the surface of the root are known to be primary root caries[12]. There is no restorative material involvement in the development of primary root caries. However, secondary root caries is the type of dental caries that can occur due to the restorative material restored in its close proximity[13]. Early detection of root caries could affect the tooth loss. Therefore, a consensus to diagnose root caries would be the first step to manage this challenging clinical problem. Hence, the aim of our study was to associate the clinical criteria used to detect root caries with DIAGNOdent readings and to detect root caries at early stage, to manage these lesions non-invasively.

## METHODS

A total of 95 teeth were collected from the Oral Surgery and Dental Emergency Department at Barts and the London, QMUL. The ethical approval was taken from Research Ethics Committee of Queen Mary University of London. Clinical assessment was carried out using the examination kit. After undergoing the clinical assessment to detect root caries, 19 out of 95 teeth were selected to perform this in-vitro study. Each selected tooth was freshly extracted since lesions would give incorrect DIAGNOdent readings after 24 hrs. This would eventually result false negative readings. Prior to recording the readings, each tooth underwent cleaning as well as polishing. Each lesion underwent examination with visual-tactile method. Furthermore, ICDAS as well as DIAGNOdent readings were retrieved.

For the determination of initial and subsequent severity of the root caries in tooth specimens, International Caries Detection and Assessment System were applied. The ICDAS root caries classification is as follows, in the Code 0 the root will appear natural with normal anatomic contour having no defects at cemento-enamel junction, which will differentiate it from the surrounding vicinity. The code 1 will show the discolored root such as light brown to dark brown or black or at the cemento-enamel junction but the anatomic contour loss will be less than 0.5mm, which will not be revealed in this code 1. The code 2 will have a demarcated area the root surface or at the cemento-enamel junction, will undergo discoloration and cavitation will exist anatomic contour will be more than 0.5mm.

The DIAGNOdent device is an instrument for detection of caries of the root with help from laser fluorescence. It can be useful for the caries diagnosis. This device is non-invasive as well as quantitative method to diagnose root caries. Even if DIAGNOdent is an important tool to diagnose the root caries lesions, nevertheless concern has been raised in regards to the accuracy[14]. In the beginning of every experiment, DIAGNOdent underwent calibration in accordance with the manual of user. Lingual as well as buccal surfaces of the root were subjected to measurement with DIAGNOdent device by applying tip of the probe that is shaped like a pen and the value that is possible ranging from 0-99. Exposed surface of root with highest reading was recorded[15].

Pearson's correlation coefficients tests were employed. Level of significance with a p value was 0.01. Each measurement calibration regarding the I.C.D.A.S, DIAGNOdent readings and clinical assessments took place by examining 40 teeth several times by the author. After 7 days, measurements again took place. Inter-examiner and intra-examiner reliability showed good agreement with a range of 80 to 90 % of scores displaying same outcomes.

## RESULTS

Clinical assessment criteria were applied for the detection of root caries. After undergoing the clinical assessment to detect root caries, 19 out of 95 teeth were selected to perform this in-vitro study. Each selected tooth was freshly extracted since lesions would give incorrect DIAGNOdent readings after 24 hrs. This would eventually result false negative readings. Freshly extracted teeth were cleaned by employing an excavator to remove the remaining periodontium and possible hard deposits on the root surface. Polishing of extracted teeth was then undertaken with a slow speed hand piece and polishing cup. Clinical assessment to detect root caries was employed. This assessment was previously studied on root caries and correlated well with the readings from the Electrical Caries Monitor (ECM) with regards to size, cavitation, and severity index 16. In this study, the severity index

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used to detect root caries was only included. Table 1 exhibits the findings regarding each lesion in terms of texture, cavitation, colour, dimension, hardness and severity index. Colour was reported as LB for light brown, DB for dark brown and B for Brown.

**Table 1: Clinical assessment criteria to detect root caries in terms of rough texture, cavitation, color, dimension, hardness and severity index.**

| No. | Cavitation | Colour | Dimension (WxH) | Hardness | Severity index |
|---|---|---|---|---|---|
| Rough Texture | | | | | |
| 1 | 2 | LB | 4x5 | Leathery | 3 |
| 2 | 2.5 | DB | 4x5 | Soft | 4 |
| 3 | 4 | DB | 4x8 | Soft | 4 |
| 4 | 0 | LB | 2x3 | Leathery | 1 |
| 5 | 0 | B | 3x1 | Hard | 0 |
| 6 | 0 | DB | 4x4 | Leathery | 1 |
| 7 | 2 | DB | 6x5 | Leathery | 3 |
| 8 | 5 | DB | 7x5 | Soft | 4 |
| 9 | 0.5 | DB | 4x2 | Leathery | 3 |
| 10 | 1 | LB | 5x4 | Leathery | 3 |
| 11 | 5 | LB | 7x7 | Soft | 4 |
| 12 | 2 | LB | 4x5 | Soft | 4 |
| 13 | 3 | LB | 6x5 | Soft | 4 |
| 14 | 5 | DB | 8x6 | Soft | 4 |
| 15 | 3 | LB | 5x6 | Soft | 4 |
| 16 | 1 | B | 2x2.5 | Leathery | 2 |
| 17 | 3 | B | 7x4 | Soft | 4 |
| 18 | 4 | LB | 7x4 | Soft | 4 |
| 19 | 3 | DB | 4x4 | Soft | 4 |

Each carious lesion of the root underwent classification in accordance with severity index. Each root carious lesion is classified according to the severity index.0 is representative of lesions that are hard. 1 is representative of lesions that are leathery. These lesions are small with easy cleaning. These lesions approach a texture that is hard. 2 is representative of lesions that are leathery. These lesions are shallow. They can be rendered free of plaque. 3 is representative of lesions that are leathery. Maintaining the sites free of plaque is not easy. Risk is associated to the integrity of the pulp. 4 is representative of lesions that are soft[16]. The clinical assessment criteria were employed as gold standard for the detection of root caries.

Estimation of depth in regards to carious lesions of the root was carried out by the recording of largest distance from between lesion surface that exists and original surface of the root. The readings of the measurements range from 0-5. With the exclusion of two specimens, there was correlation in regards to the texture as well as the cavitation of specimens. Shade guide was used for lesions that are black, light brown, dark brown and yellow. The guide was employed for classification of lesions. The lesions of the specimens had either light brown, dark brown or black colour. No correlation can be demonstrated in regards to the colour with the texture and cavitations of these lesions. Colour was also found to be not correlated with severity of root carious lesions[12,16]. Based upon colour as well as hardness of area affected by root caries, there has been an acceptance of visual examination as the tool which is best for diagnosing caries whose size is small.

A total of 19 out of 95 freshly extracted teeth were chosen to carry out the assessments and measurements for this in vitro study. Code 0: showed root surface with no "signs of discoloration" or defects. Hence, it does not have "root caries". Code 1: showed a demarcated area on the surface of root. The root surface has none or small cavitation (0.5)mm. Code 2: shows discolored area in relation to "root surface". There is cavitation (0.5)mm.

The DIAGNOdent device is an instrument for detection of caries of the root with help from laser fluorescence. It can be useful for the diagnosis of caries of the root. In the beginning of every experiment, DIAGNOdent underwent calibration in accordance with the manual of user. Lingual as well as buccal surfaces of the root were subjected to measurement with DIAGNOdent device by applying tip of the probe that is shaped like a pen and the value that is possible is in the range of 0-99. Highest reading on every exposed surface of root underwent recording[17,18]. Figure 1 showed the wide range of DIAGNOdent regarding with ICDAS scores whilst Table 2, reported the significant correlations between ICDAS scores with cavitation, size and hardness respectively.

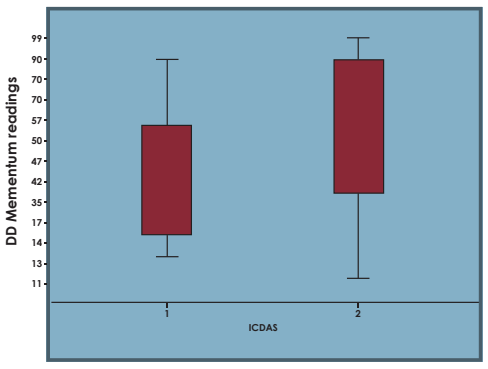


**Figure 1: DIAGNOdent momentum readings in relation to ICDAS scores.**

**Table 2: Correlation between cavitation, lesion size, hardness and ICDAS scores.**

| Correlations (n=19) | Spearman's rho | ICDAS | Correlation Coefficient/ *p*-Value |
|---|---|---|---|
| **Correlation between cavitation and ICDAS scores** | ICDAS Correlation Coefficient<br>Sig.(2-tailed) | 1.000 | 0.703**<br>0.001 |
| Correlation between size and ICDAS scores | Size Correlation Coefficient<br>Sig.(2-tailed) | 0.703**<br>0.001 | 1.000 |
| **Correlation between lesion size and ICDAS Scores** | ICDAS Correlation Coefficient<br>Sig.(2-tailed) | 1.000 | 0.662<br>0.003 |
| Correlation between size and ICDAS scores | ICDAS Correlation Coefficient<br>Sig.(2-tailed) | 0.622**<br>0.003 | 1.000 |
| **Correlations between lesion hardness and ICDAS scores** | ICDAS Correlation Coefficient<br>Sig.(2-tailed) | 1.000 | 0.654<br>0.002 |
| Correlation between size and ICDAS scores | ICDAS Correlation Coefficient<br>Sig.(2-tailed) | 0.654**<br>0.002 | 1.000 |

***Correlation is significant at the 0.01 level (2-tailed).*

The correlation between cavitation and ICDAS scores shows the significant value of 0.01 (2-tailed) as the spearman's correlation coefficient score for ICDAS score is 1 and 0.73 for cavitation and vice versa for cavitation correlation coefficient. The correlation between size of the lesion and ICDAS scores shows the significant value of 0.01 (2-tailed) as the spearman's correlation coefficient score for size of the lesion score is 0.622 and 1 for cavitation and 1 for ICDAS and 0.622 for spearman ICDAS correlation coefficient. The correlation between lesion hardness and ICDAS scores shows the significant value of 0.01 (2-tailed) as the spearman's correlation coefficient score for ICDAS score is 1 and 0.65 for cavitation and vice versa for spearman's hardness correlation coefficient (Table 2). The "Mean" and "Standard Deviation" for the DIAGNOdent reading with momentum and peak values were 45.37 for momentum with standard deviation of 32.16 and for peak with the mean value of 49.79 and 31.72 of standard deviation. Spearman's correlation test failed to show any correlation between the severity index and DIAGNOdent momentum readings. Thus, 19 teeth were given scores according to I.C.D.A.S. 15 teeth had scores of 2.2 is representative of a well-demarcated area on surface of the root. The cavitation exceeded 5mm. Only 4 teeth had scores of 1. This shows that more teeth have progressed to the point of non-restoration.

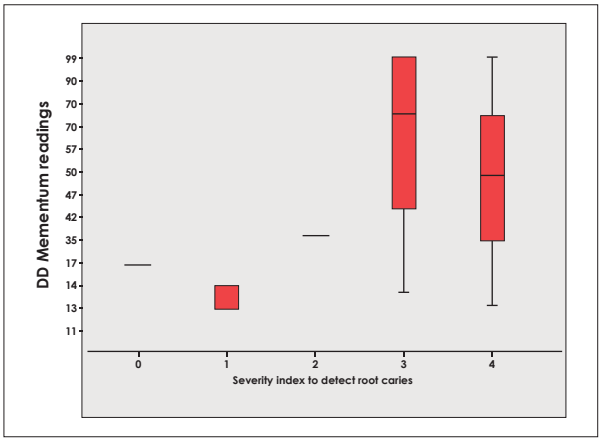


**Figure 2: Box plot of DIAGNOdent momentum readings according to severity index.**

The box plot of DIAGNOdent momentum is seen in the Figure 2 the readings depict the severity index of root caries. The DIAGNOdent device employed for quantifying the severity of root caries. The DIAGNOdent yielded readings that were high in regards to surfaces of the root that were smooth or intact and vice-versa. There were inconsistent readings, which had false positive outcomes. Correlation was difficult to establish in regards to clinical assessment to detect root caries. Correlation is difficult to establish in between values of DIAGNOdent and codes of I.C.D.A.S. For e.g. I.C.D.A.S score of specimen 1 is 2.2 is representative of an area which is demarcated clearly on surface of the root or C.E.J which exhibits discolouration (light brown/ dark brown,

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black) and cavitation (anatomical contour loss (0.5)mm is present. However, values of DIAGNOdent are less (momentum=14, peak=19). Regarding, readings of DIAGNOdent and severity index establishment of correlation was difficult to establish. For e.g. Score of severity index regarding specimen no.1 is 3.3 is representative of lesion that is leathery. The integrity of the pulp is at risk. However, the values of DIAGNOdent are less in comparison. Value of momentum is 14, and value of peak is 19.

## DISCUSSION

In total, 19 teeth were given scores according to I.C.D.A.S. 15 teeth had scores of 2.2 is representative of a well-demarcated area on surface of the root. The cavitation exceeded 5mm. Only 4 teeth had scores of 1. This shows that more teeth have progressed to the point of non-restoration. The clinical assessment criteria were employed as gold standard for the detection of root caries. Estimation of depth in regards to carious lesions of the root was carried out by the recording of largest distance from between lesion surface that exists and original surface of the root. The readings of the measurements range from 0-5. With the exclusion of two specimens, there was correlation in regards to the texture as well as the cavitation of specimens. Shade guide was used for lesions that are black, light brown, dark brown and yellow. The guide was employed for classification of lesions.

The lesions of the specimens had either light brown, dark brown or black colour. No correlation can be demonstrated in regards to the colour with the texture and cavitations of these lesions. Colour was also found to be not correlated with severity of root carious lesions. Based upon colour as well as hardness of area affected by root caries, there has been an acceptance of visual examination as the tool which is best for diagnosing caries whose size is small[19-23]. However, since its sensitivity is low, the ability for detection of region that is carious is poor. Furthermore, employment of dental probe for visual examination could be very helpful for diagnosing caries. Nevertheless, fissures as well as enamel that are demineralised can be damaged by sharp and forceful probing. Hence, process of caries will progress.

Additionally, to correlate the I.C.D.A.S scores with severity index used to detect root caries and DIAGNOdent readings. DIAGNOdent is helpful instrument for improvement of sensitivity as well as specificity in combination with the "visual-tactile" detecting regarding early caries of the root. Performance of radiographs as adjunct for assessment of caries of the root is poor, especially early lingual and buccal caries assessment[24-27].

The difference was significant in values of DIAGNOdent between sound and carious lesions, which diagnosed with visual-tactile assessments that support validation of DIAGNOdent for root caries. However, the readings were unable to differentiate the lesions by their severity. DIAGNOdent could be employed as adjunct for detection of root caries. However, for clinical diagnosis, the requisite is visual-tactile[15]. The DIAGNOdent device employed for quantifying the severity of root caries. The DIAGNOdent yielded readings that were high in regards to surfaces of the root that were smooth or intact and vice-versa. There were inconsistent readings, which had false positive outcomes. Correlation was difficult to establish in regards to clinical assessment to detect root caries. Thus, 19 teeth were given scores according to I.C.D.A.S. and 15 teeth had scores of 2.2 is representative of a demarcated area on root surface. The cavitation exceeded 5mm. Only 4 teeth had scores of 1.

This shows that more teeth have progressed to the point of non-restoration. Correlation is difficult to establish in between values of DIAGNOdent and codes of I.C.D.A.S. For e.g. I.C.D.A.S score of specimen 1 is 2.2 is representative of an area which is demarcated clearly on surface of the root or C.E.J which exhibits discolouration of light brown to dark brown or black and cavitation (anatomical contour loss more than 0.5mm) is present. However, values of DIAGNOdent are less (momentum=14, peak=19). Regarding, readings of DIAGNOdent and severity index establishment of correlation was difficult to establish. For e.g. Score of severity index regarding specimen no.1 is 3.3 is representative of lesion that is leathery. The integrity of the pulp is at risk. However, the values of DIAGNOdent are less in comparison. Value of momentum is 14, and value of peak is 19.The correlation between the Severity Index as well as the I.C.D.A.S was poor. There is no correlation of I.C.D.A.S and DIAGNOdent device. Similarly, there is no relationship between Severity Index as well as the DIAGNOdent device. Thus, there is no correlation between the I.C.D.A.S, Severity Index and DIAGNOdent. Nevertheless, further investigation is needed in vitro and in vivo[15].

## CONCLUSION

The severity index scoring system is in need of greater categories regarding to caries of the root. DIAGNOdent was presented as being suitable for detecting caries of the root. The employment of the DIAGNOdent is considered not sufficient for providing plan of treatment.

## ACKNOWLEDGMENTS

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## CONFLICT OF INTEREST

There was no conflict of interest among the authors.

## ETHICS APPROVAL

The ethical approval was taken from Research Ethics Committee of Queen Mary University of London.

## PATIENT CONSENT

Verbal and written informed consent was obtained from all patients.

## AUTHORS' CONTRIBUTION

FT and RA start this idea with extraction of supporting papers from electronic databases and formation of questionnaire and collection of data. MR and RSK equally contribute with first two authors in the compilation and designing the table and figures.

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