Sensitivity and specificity of air-drying and magnification in detection of initial caries on occlusal surfaces

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Objective-*The aim of this study was to assess the effect of magnification and air-drying on detection of carious lesion.* **Study Design-***44 human extracted premolars were selected with sound occlusal surfaces without frank cavitation. The Diagnostic techniques used were Unaided visual examination, Magnifying Loupes (4.2x) and Stereomicroscope (10x, before and after air-drying) and then the teeth were sectioned bucco-lingually and both the surfaces were examined under Stereomicroscope (50x) to assess the presence or absence of carious lesion in the pit and fissures. The scores were compared to obtain Cohen's kappa coefficient (Reproducibility) and subjected to the Friedman Test and Paired t test. Sensitivity, specificity and positive predictive value used to assess accuracy.* **Results-***On Statistical analysis, visual examination before and after air drying had highest specificity but lowest sensitivity compared to different diagnostic techniques. Magnifying loupes after air-drying had highest sensitivity and lowest specificity compared to other diagnostic techniques.* **Conclusion-***Air drying combined with magnifying aids are cost-effective, reliable method for detection of early carious lesion. If used in pediatric clinical practice, any undesirable pain and discomfort to the patient due to invasive procedures and helps in employing preventive measures.*

Key words: Stereomicroscope, Magnifying Loupes, Unaided visual examination, Cohen's Kappa Test, Paired t-test.

INTRODUCTION

Dental caries is a dynamic process of alternating demineralization and remineralisation[1-3] The demineralization may begin soon after eruption of the tooth in the oral cavity without being recognised by dental professionals.[3-5] Occlusal caries in particular is difficult to diagnose at an early stage.[6] The fissure which clinically appears caries free, may histologically show signs of incipient lesion formation or extensive caries underneath it.[2,6] Early and accurate diagnosis can help in the prevention of formation of new lesions and arrest in the progression of old lesions in children.[7-8] An ideal diagnostic method should be objective, quantitative, non-invasive and cost-effective and safe for pediatric patients as well as the dentist.[9] Literature shows that unaided visual examination can detect less than 50% of carious lesions.[10] Recently introduced diagnostic aids such as Fibre-Optic Transillumination, Diagnodent, Optical Coherence Tomography and Radiovisiography act as adjunct to unaided visual examination, however, all these methods are technique sensitive, expensive and pose a risk of unwanted radiation exposure (Table 1 and 2).[10]

To overcome the above mentioned drawbacks, magnification can be used as an adjunct to visual examination. Most commonly used magnifying aid in clinical practice is magnifying loupes which are reasonably affordable, easily operated and readily accessible.[10] A clinically relevant benefit of using magnification is that it can be used for diagnosis on all tooth surfaces, unlike most of the other methods which are suitable only for single surface examination.[10] Visual examination with magnifying aids combined with air drying and proper isolation provides better specificity and reproducibility of caries detection as saliva present on the tooth surface may hinder with the detection of an early carious lesion due to difference in the refractive index of enamel, water and air.[10,11]

Thus the present in vitro study was undertaken to evaluate and compare the effectiveness of air drying and magnification for detection of initial caries on relatively intact occlusal surfaces of human premolar teeth using three different diagnostic aids (unaided visual examination, magnifying loupes and stereomicroscope).

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Table 1: Advantages and disadvantages of the different devices[a,b]

S.no	Diagnostic Aid	Advantages	Disadvantages
1.	Digital Substraction Radiography	Image acquisition in real time No processing required Reduction in radiation dose	Technique sensitive Very sensitive to any physical noise occurring between the radiographs and even minor changes lead to large errors in results.
2.	Fibre-optic Transillumination (FOTI)/(DIFOTI)	Practical, easy, fast. DIFOTI presents higher sensitivity in detection early lesions when compared to the radiographic examination	FOTI diagnosis by naked eye can be subject to great inter- and intra-examiner variation. Low sensitivity.
3.	DIAGNOdent	Measure both sensitivity and specificity of lesions. Can be used in pediatric cases where radiographic examination not possible. Useful in cases with special needs.	Presence of stains leads to false-positive results. Needs to be validated visually and by other techniques also. Technique sensitive as various factors affect the results like stain, calculus, cut-off points for enamel and dentin caries and calibration procedures.
4.	Electrical Caries Monitor (ECM)	Operates over different frequencies thus determine differences more accurately. Can be used on both occlusal and proximal surfaces.	Presence of stain is a confounder for ECM measurements. More in-vivo studies are required.
5.	Quantitative Light-induced Fluorescence	Possible to detect and differentiate caries lesions at an early stage of development. The image can be stored and used to motivate patients.	Method is more complicated, since the use of QLF consists of three main steps. Can be influenced by some factors, such as stains, dental plaque, dental fluorosis or hypomineralization.
6.	Optical Coherence Tomography (OCT)	High spatial resolution. Real-time, two dimensional depth visualization. External factors do not affect the measurements.	Technique not yet developed into commercially available devices.
7.	Cone beam Computed Tomography (CBCT)	Utilizes the least amount of radiation. Less exposure time. Three- dimensional images	Initial investment is high. Large space required for set-up of machine. Technique sensitive.

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Table 2: Sensitivity and specificity of the different devices [a,b,c]

Devices	Sensitivity	Specificity
Visual Inspection	0.6	0.73
Fibre-optic Transillumination	0.21	0.88
Bitewing Radiograph	0.19	0.80
Electronic Caries Monitor	0.65	0.73
DIAGNOdent	0.87	0.5
Quantitative laser fluorescence	0.5-0.68	0.7-0.9

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MATERIALS AND METHOD

Forty-four freshly extracted intact, visually caries free human premolars, indicated for extraction for orthodontic purposes were selected for the present study. Teeth were then autoclaved according to Occupational Safety and Health Administration guidelines. All samples were assessed for caries using three diagnostic methods using naked eye, magnifying loupes, and stereomicroscope with inter-examiner blinding using three different trained examiners.

The occlusal surfaces of all the samples were assessed using the following techniques:

Technique 1: The occlusal surfaces of all the samples assessed before air drying

- Technique 1(a): The occlusal surfaces of all the samples assessed before air drying with Naked eye.
- Technique 1(b): The occlusal surfaces of all the samples assessed before air drying with Magnifying loupes (4.2x magnification, Amtec, India)
- Technique 1(c): The occlusal surfaces of all the samples assessed before air drying under stereomicroscope (10x magnification) (Zoom Stereomicroscope, Olympus Optical Co., Japan)

Technique 2: The occlusal surfaces of all the samples assessed after air drying.

- Technique 2(a): The occlusal surfaces of all the samples assessed after air drying with Naked eye.
- Technique 2(b): The occlusal surfaces of all the samples assessed after air drying with Magnifying loupes (4.2x magnification, Amtec, India)
- Technique 2(c): The occlusal surfaces of all the samples assessed after air drying under stereomicroscope (10x magnification) (Zoom Stereomicroscope, Olympus Optical Co., Japan)

Scoring Criteria:

All the samples were assessed according to the above mentioned techniques and the scores were recorded as:

Score 0- Absence of discoloration or cavitation

Score 1- Presence of discoloration or cavitation

For example, score obtained for Sample 1 using Technique 1 (c) was 0 (Figure 1) and using Technique 2 (c) was scored 1 (Figure 2).

Histological Evaluation for validation:

After examining all samples with above mentioned techniques, samples were subjected to histological examination to confirm the presence or absence of a carious lesion. Each sample was hemi-sectioned in bucco-lingual diection using a diamond disc mounted on a slow speed handpiece and each section was viewed under stereomicroscope (50x magnifications) (Figure 3). Sections of each tooth were scored according to the scoring criteria mentioned above by the fourth examiner.

Statistical Analysis:

Data was analyzed on SPSS V.16 Statistical software. Paired-t test was used to compare the scores within various detection methods. The agreement between the various diagnostic techniques was analyzed by Friedman test and reproducibility was measured by Cohen kappa scores, values of which range from 0 for less than chance agreement to 1 for almost perfect agreement. A 2x2 contingency table (Figure 4) was created to classify clinical findings as true positive, true negative, false positive or false negative to assess the sensitivity, specificity and positive predictive value used to assess accuracy.

Figure 1 – shows occlusal surface of Sample 1 using Technique 1 (c) was given a score of 0 as no discoloration/ cavitation was observed

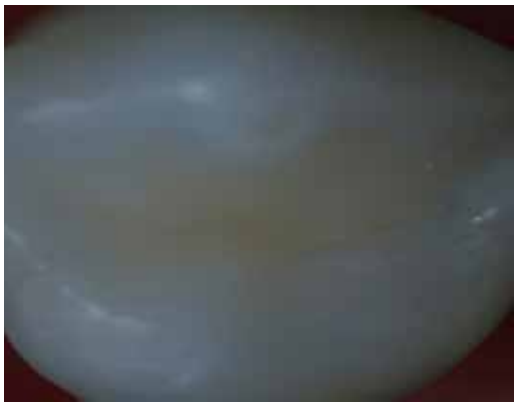

Figure 2 – shows occlusal surface of Sample 1 using Technique 2 (c) was given a score of 1 as discoloration/cavitation was observed

Figure 3 – shows histological section of Sample 1 observed under Stereomicroscope (50x magnification) which was given a score of 1 due to presence of carious pit/ fissures.

Figure 4- Two*two contingency table for classification of clinical findings: (TP) True-Positive; (TN) True-Negative; (FP) False-Positive; (FN) False-Negative. Sensitivity= TP/ (TP+FN); Specificity= TN/(TN+FP); Positive Predictive Value= TP/(TP+FP)

		Histological examination	
		Sound	Diseased
Diagnostic Techniques	Sound	TN	FN
	Diseased	FP	TP

RESULTS

Result of statistical analysis:

Table 3 shows comparison between various diagnostic techniques before and after air drying using Paired t-test. On applying Paired t-test, significant difference between the mean scores of techniques 1(b)-2(b), 1(a)-1(b), 1(b)-1(c), 1(a)-1(c), 2(a)-2(b), 2(b)-2(c) and 2(a)-2(c) ($p<0.05$) was found with maximum Mean score seen in Technique 2(b) (0.95).

Table 4 represents distribution of mean ranks after applying Friedman Test for all the diagnostic techniques. On applying Friedman test, a highly significant difference was found between all the diagnostic methods as p value was less than 0.05($p=0.000$).

Table 5 depicts measurement of reproducibility and comparison of agreement between the various caries detection techniques using Cohen Kappa Test. A highly significant Kappa (reproducibility) score of 0.703and 0.692 (range 0.61-0.80) between techniques **1(b)** [Before air drying with magnifying loupes (4.2 x magnification)] **- 1(c)** [Before air drying with Stereomicroscope (10x magnification)]; and between **1(a)** [Before air drying with Naked eye] **- 2(a)** [After air drying with Naked eye] was seen ($p=0.000$) showing significant reproducibility for the given diagnostic techniques.

Table 6 illustrates Sensitivities, Specificities, and Positive Predictive values of various diagnostic techniques (compared with histological analysis). Maximum sensitivity was seen for technique **2(b)** [After air drying with magnifying loupes (4.2 x magnification)] (97.2%) and maximum specificity and positive predictive value was seen for technique **1(a)** [Before air drying with Naked eye] (100%) and **2(a)** [After air drying with Naked eye] (100%) respectively.

Table 3: Comparison between various diagnostic techniques before and after air drying using t-test

Technique	Mean ± Std. Deviation Of Score	p Value	N
1(a) - Before air drying with Naked eye	.09 ± .291	0.083	
2(a) - After air drying with Naked eye	.16 ± .370		
1(b) - Before air drying with magnifying loupes (4.2 x magnification)	.59 ± .497	0.000*	
2 (b) - After air drying with magnifying loupes(4.2x magnification)	.95 ± .211		
1(c) - Before air drying with Stereomicroscope (10x magnification)	.73 ± .451	0.160	
2(c) - After air drying with Stereomicroscope (10x magnification)	.82 ± .390		
1(a) - Before air drying with Naked eye	.09 ± .291	0.000*	
1(b) - Before air drying with magnifying loupes (4.2 x magnification)	.59 ± .497		
1(b) - Before air drying with magnifying loupes (4.2 x magnification)	.59 ± .497	0.013*	
1(c) - Before air drying with Stereomicroscope (10x magnification)	.73 ± .451		44
1(a) - Before air drying with Naked eye	.09 ± .291	0.000*	
1(c) - Before air drying with Stereomicroscope (10x magnification)	.73 ± .451		
2(a) - After air drying with Naked eye	.16 ± .370	0.000*	
2 (b) - After air drying with magnifying loupes(4.2x magnification)	.95 ± .211		
2(b) - After air drying with magnifying loupes(4.2x magnification)	.95 ± .211	0.013*	
2(c) - After air drying with Stereomicroscope (10x magnification)	.82 ± .390		
2(a) - After air drying with Naked eye	.16 ± .370	0.000*	
2(c) - After air drying with Stereomicroscope (10x magnification)	.82 ± .390		

*- Significant p Value < 0.05

Table 4- Distribution of mean ranks after applying Friedman Test for all the diagnostic techniques.

Diagnostic Technique	Mean Rank	N	Chi square	df	p value
1(a) - Before air drying with Naked eye	2.24	44	139.672	6	0.000*
2(a) - After air drying with Naked eye	2.48				
1(b) - Before air drying with magnifying loupes (4.2 x magnification)	3.99				
2(b) - After air drying with magnifying loupes (4.2 x magnification)	5.26				
1 (c) - Before air drying with Stereomicroscope (10x magnification)	4.47				
2 (c) - After air drying with Stereomicroscope (10x magnification)	4.78				
Histological Sections – Under Stereomicroscope (50x magnification)	4.78				

*- Significant p Value < 0.05

Table 5- Measurement of reproducibility and comparison of agreement between the various caries detection techniques using Cohen Kappa Test

Diagnostic Techniques	N	Kappa Value	p Value
1(a) – 2(a)	44	0.692	0.000*
1(b) – 2(b)	44	0.129	0.082
1(c) – 2(c)	44	0.488	0.001*
1(a) – 1(b)	44	0.129	0.081
1(b) – 1(c)	44	0.703	0.000*
1(a) – 1(c)	44	0.072	0.199
2(a) – 2(b)	44	0.018	0.529
2(b) – 2(c)	44	0.353	0.002*
2(a) – 2(c)	44	0.017	0.771

*- Significant p Value < 0.005

Table 6- Sensitivities, Specificities, and Positive Predictive values of various diagnostic techniques (compared with histological analysis)

Diagnostic Techniques	Sensitivity (%)	Specificity (%)	Positive Predictive Value (%)
1(a)	11.1	100	100
2(a)	19.4	100	100
1(b)	66.7	75	92.3
2(b)	97.2	12.5	83.4
1(c)	80.6	62.5	90.62
2(c)	88.9	50	88.9

DISCUSSION

Various methods for dental caries diagnosis have been used in the last few decades, but visual inspection still claims to be the most commonly used diagnostic method in populations with low caries prevalence. But it is ineffective in correctly diagnosing early carious lesion because of low sensitivity of visual inspection alone.[4,8,12] Visual inspection of caries is carried out by using a probe in clean dry conditions.[13] This can cause transmission of cariogenic flora from one infected site to another,[2,3,12] which may also lead to traumatic defects in potentially remineralizable enamel.[10] Magnification is a common aid for diagnosis which overcomes the various drawbacks of unaided visual exmination.[14] It increases the number of correctly identified lesions which allows for various preventive measures to be used effectively for incipient lesion.[10] Currently used magnifying aids such as magnification eyeglasses, stereomicroscope and also digital imaging with magnification have been proved to be effective in proximal caries detection.[14]

The most important aspect of diagnosis of early caries is that the surface must be dry because saliva can mask differences in the reflection of light between carious and healthy tooth structure, hindering the observation of changes in colour and brightness on the enamel surface. White spots are more visible when teeth are dry because of the difference in the refractive indices of enamel, water and air.[2,11] Shi et al reported a systematic difference between data from the same registration under wet and dry conditions on occlusal surfaces.[15] Braga et al (2010) stated that there are 29 different visual criteria for detecting caries lesion but only about half of the technologies recommend teeth to be cleaned and/or dried before the examination process, which if not included increases the risk of missing lesions which are not seen under naked eye examination.[8] Visual inspection can be combined with air-drying, proper isolation of the tooth and use of magnification for greater specificity in diagnosis of early carious lesions.[10,11]

Thus, the present study aimed to evaluate the effectiveness of air-drying and magnification technique for detection of initial caries on relatively intact or caries free occlusal surfaces of human premolars. In the present study, Unaided-visual inspection, Magnifying loupes (4.2 X) and Stereomicroscope (10X) were used for diagnosis of initial caries before and after air-drying the occlusal surface and a highly significant difference ($p<0.05$) was found between all three methods (Table 4).

Results (Table 3) showed highly significant difference ($p<0.001$) using magnifying loupes for diagnosis before and after air-drying [1(b)-2(b)]. When Magnifying loupes and Stereomicroscope were compared (Table 3) for caries diagnosis before and after air-drying, a statistically significant ($p<0.05$) difference was observed between the two methods [1(b)-1(c); 2(b)-2(c)]. Also, a highly significant difference ($p<0.001$) was found on comparing unaided- visual examination with magnifying loupes and stereomicroscope before and after air drying (Table 3).

Improved results with highest sensitivity (97.2%) were seen when magnifying loupes along with air-drying were used (Table 6). Results showed that the caries detection rate increased when samples were evaluated after air-drying using magnifying loupes

(4.2 X) as diagnostic methods. This is in agreement with findings of Pinelli et al who stated that air-drying the tooth surface before examination increases the reproducibility of caries detection rate using Diagnodent and also recommended drying of tooth surface for 10 seconds to assure reliability in diagnosis of carious lesions.[16] Fibreoptic Transillumination (FOTI) is one of the newer clinical methods of caries diagnosis developed by Marcus and Friedman in 1970. On illumination of a tooth due to presence of porosities the light gets scattered, enamel appears as white opaque area. FOTI uses a high-intensity white light and carious enamel and dentin are seen as shadows.[8] Studies have shown that visual inspection is as accurate as FOTI in detecting occlusal caries and provides high sensitivity compared to radiographic method and Diagnodent.[17-19] Hintz et al also stated stereomicroscopy as the only method that correctly identified all unerupted teeth as sound, resulting in specificity of 1.00, whereas all other inspection method (film radiography, microradiography and naked eye examination) resulted in false-positive carious results for sound teeth.[20] Erten et al also stated that operating microscope improved occlusal caries detection as compared to visual examination alone.[21] Study done by Silva- Neto et al revealed that nearly half of the surfaces diagnosed as clinically sound showed incipient carious involvement at enamel level under stereomicroscopy that had not been detected during visual inspection. [22]

Angnes et al and Reis et al found magnification and laser fluorescence did not significantly alter the specificity of diagnosis compared to unaided vision as the maintenance of high levels of specificity will prevent overtreatment.[12,23] This is in agreement with the findings of Haak et al who reported that prism loupe or surgical microscope did not improve the validity of proximal caries detection.[24] Peker et al in an in-vitro study found that the efficiency of operating microscope was statistically equal with unaided visual examination and lower than film and digital radiography for proximal caries lesion detection.[14] As stereomicroscope cannot be used in clinical practice, similar magnification can be achieved by the use of Operating Microscopes for detection of caries but as operating microscopes are expensive, technique sensitive and require experience there is a probability that accurate diagnosis of carious lesion will not be improved.

Visual examination alone does not provide enough details on examination but the use of low-powered magnification significantly improves the accuracy of examination. Use of magnification devices is easy, less technique sensitive and less time consuming Therefore magnification can be integrated into clinical practice without much alteration to scheduling procedure.[10,14] But as the technology had advanced, various new diagnosing techniques have been introduced in clinical practice. Further studies are required to validate the results of this study in-vivo with air-drying and magnifying loupes and to compare the diagnostic efficiency of magnification devices to other diagnostic methods available.

Relevance in Pediatric Dentistry-

Early diagnosis of initial caries in children using the above mentioned magnification and air drying techniques would help prevent their progression and development of new carious lesions thus creating a healthy oral environment instilling a positive attitude in children as well as parents towards dental treatment.

CONCLUSION

- Visual examination before and after air drying had highest specificity but lowest sensitivity compared to different diagnostic techniques.
- Magnifying loupes after air-drying had highest sensitivity and lowest specificity compared to other diagnostic techniques.
- Air drying combined with magnifying aids is cost-effective, reliable method for detection of early carious lesion. If used in clinical practice, any undesirable pain and discomfort to the patient can be reduced thus helps in employing preventive measures.

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