P980025

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

Food and Drug Administration
9200 Corporate Boulevard
Rockville MD 20850

David C. Gakenheimer, Ph.D.
Manager, Applied Physics Division
Logicon RDA
6053 West Century Blvd.
P.O. Box 92500
Los Angles, CA 90009

SEP 25 1998

Re: P980025
Logicon Caries Detector™
Filed: June 18, 1998
Amended: July 27, August 7 and September 8, 1998

Dear Dr. Gakenheimer:

The Center for Devices and Radiological Health (CDRH) of the Food and Drug Administration (FDA) has completed its review of your premarket approval application (PMA) for the Logicon Caries Detector™. The Logicon Caries Detector™ is a software decision aid for the diagnosis of caries that have penetrated into the dentin, on unrestored proximal surfaces of secondary dentition, through the analysis of digital intra-oral radiographic imagery. It is intended as an adjunct designed to work in conjunction with existing Trextrophy RVG digital x-ray radiographic system with TWI Software Version 3.0 or higher. We are pleased to inform you that the PMA is approved subject to the conditions described below and in the "Conditions of Approval" (enclosed). You may begin commercial distribution of the device upon receipt of this letter.

The sale, distribution and use of this device are restricted to prescription use in accordance with 21 CFR 801.109.

CDRH will notify the public of its decision to approve your PMA by making available a summary of the safety and effectiveness data upon which the approval is based. The information can be found on the FDA CDRH Internet HomePage located at http://www.fda.gov/cdrh/pmapage.html. Written requests for this information can also be made to the Dockets Management Branch, (HFA-305), Food and Drug Administration, 5630 Fishers Lane, Rm. 1061, Rockville, MD 20852. The written request should include the PMA number or docket number. Within 30 days from the date that this information is placed on the Internet, any interested person may seek review of this decision by requesting an opportunity for administrative review, either through a hearing or review by an independent advisory committee, under section 515(g) of the Federal Food, Drug, and Cosmetic Act (the act).

Failure to comply with the conditions of approval invalidates this approval order. Commercial distribution of a device that is not in compliance with these conditions is a violation of the act.

You are reminded that, as soon as possible and before commercial distribution of your device, you must submit an amendment to this PMA submission with copies of all approved labeling in final printed form.

All required documents should be submitted in triplicate, unless otherwise specified, to the address below and should reference the above PMA number to facilitate processing.

PMA Document Mail Center (HFZ-401)
Center for Devices and Radiological Health
Food and Drug Administration
9200 Corporate Blvd.
Rockville, Maryland 20850

If you have any questions concerning this approval order, please contact Joseph S. Arnaudo at (301) 594-1212.

Sincerely yours,

Susan Alpert, M.D.
Director
Office of Device Evaluation
Center for Devices and
Radiological Health

Enclosure

Issued: 3-4-98

CONDITIONS OF APPROVAL

APPROVED LABELING. As soon as possible, and before commercial distribution of your device, submit three copies of an amendment to this PMA submission with copies of all approved labeling in final printed form to the PMA Document Mail Center (HFZ-401), Center for Devices and Radiological Health, Food and Drug Administration (FDA), 9200 Corporate Blvd., Rockville, Maryland 20850.

ADVERTISEMENT. No advertisement or other descriptive printed material issued by the applicant or private label distributor with respect to this device shall recommend or imply that the device may be used for any use that is not included in the FDA approved labeling for the device. If the FDA approval order has restricted the sale, distribution and use of the device to prescription use in accordance with 21 CFR 801.109 and specified that this restriction is being imposed in accordance with the provisions of section 520(e) of the act under the authority of section 515(d)(1)(B)(ii) of the act, all advertisements and other descriptive printed material issued by the applicant or distributor with respect to the device shall include a brief statement of the intended uses of the device and relevant warnings, precautions, side effects and contraindications.

PREMARKET APPROVAL APPLICATION (PMA) SUPPLEMENT. Before making any change affecting the safety or effectiveness of the device, submit a PMA supplement for review and approval by FDA unless the change is of a type for which a "Special PMA Supplement-Changes Being Effected" is permitted under 21 CFR 814.39(d) or an alternate submission is permitted in accordance with 21 CFR 814.39(e). A PMA supplement or alternate submission shall comply with applicable requirements under 21 CFR 814.39 of the final rule for Premarket Approval of Medical Devices.

All situations which require a PMA supplement cannot be briefly summarized, please consult the PMA regulation for further guidance. The guidance provided below is only for several key instances.

A PMA supplement must be submitted when unanticipated adverse effects, increases in the incidence of anticipated adverse effects, or device failures necessitate a labeling, manufacturing, or device modification.

A PMA supplement must be submitted if the device is to be modified and the modified device should be subjected to animal or laboratory or clinical testing designed to determine if the modified device remains safe and effective.

A "Special PMA Supplement - Changes Being Effected" is limited to the labeling, quality control and manufacturing process changes specified under 21 CFR 814.39(d)(2). It allows for the addition of, but not the replacement of previously approved, quality control specifications and test methods. These changes may be implemented before FDA approval upon acknowledgment by FDA that the submission is being processed as a "Special PMA Supplement - Changes Being Effected." This acknowledgment is in addition to that issued by the PMA Document Mail Center for all PMA supplements submitted. This procedure is not applicable to changes in device design, composition, specifications, circuitry, software or energy source.

Alternate submissions permitted under 21 CFR 814.39(e) apply to changes that otherwise require approval of a PMA supplement before implementation of the change and include the use of a 30-day PMA supplement or annual postapproval report. FDA must have previously indicated in an advisory opinion to the affected industry or in correspondence with the applicant that the alternate submission is permitted for the change. Before such can occur, FDA and the PMA applicant(s) involved must agree upon any needed testing protocol, test results, reporting format, information to be reported, and the alternate submission to be used.

POSTAPPROVAL REPORTS. Continued approval of this PMA is contingent upon the submission of postapproval reports required under 21 CFR 814.84 at intervals of 1 year from the date of approval of the original PMA. Postapproval reports for supplements approved under the original PMA, if applicable, are to be included in the next and subsequent annual reports for the original PMA unless specified otherwise in the approval order for the PMA supplement. Two copies identified as "Annual Report" and bearing the applicable PMA reference number are to be submitted to the PMA Document Mail Center (HFZ-401), Center for Devices and Radiological Health, Food and Drug Administration, 9200 Corporate Blvd., Rockville, Maryland 20850. The postapproval report shall indicate the beginning and ending date of the period covered by the report and shall include the following information required by 21 CFR 814.84:

(1) Identification of changes described in 21 CFR 814.39(a) and changes required to be reported to FDA under 21 CFR 814.39(b).

(2) Bibliography and summary of the following information not previously submitted as part of the PMA and that is known to or reasonably should be known to the applicant:

> (a) unpublished reports of data from any clinical investigations or nonclinical laboratory studies involving the device or related devices ("related" devices include devices which are the same or substantially similar to the applicant's device); and
>
> (b) reports in the scientific literature concerning the device.

If, after reviewing the bibliography and summary, FDA concludes that agency review of one or more of the above reports is required, the applicant shall submit two copies of each identified report when so notified by FDA.

ADVERSE REACTION AND DEVICE DEFECT REPORTING. As provided by 21 CFR 814.82(a)(9), FDA has determined that in order to provide continued reasonable assurance of the safety and effectiveness of the device, the applicant shall submit 3 copies of a written report identified, as applicable, as an "Adverse Reaction Report" or "Device Defect Report" to the PMA Document Mail Center (HFZ-401), Center for Devices and Radiological Health, Food and Drug Administration, 9200 Corporate Blvd., Rockville, Maryland 20850 within 10 days after the applicant receives or has knowledge of information concerning:

(1) A mix-up of the device or its labeling with another article.

(2) Any adverse reaction, side effect, injury, toxicity, or sensitivity reaction that is attributable to the device and

(a) has not been addressed by the device's labeling or

(b) has been addressed by the device's labeling, but is occurring with unexpected severity or frequency.

(3)Any significant chemical, physical or other change or deterioration in the device or any failure of the device to meet the specifications established in the approved PMA that could not cause or contribute to death or serious injury but are not correctable by adjustments or other maintenance procedures described in the approved labeling. The report shall include a discussion of the applicant's assessment of the change, deterioration or failure and any proposed or implemented corrective action by the applicant. When such events are correctable by adjustments or other maintenance procedures described in the approved labeling, all such events known to the applicant shall be included in the Annual Report described under "Postapproval Reports" above unless specified otherwise in the conditions of approval to this PMA. This postapproval report shall appropriately categorize these events and include the number of reported and otherwise known instances of each category during the reporting period. Additional information regarding the events discussed above shall be submitted by the applicant when determined by FDA to be necessary to provide continued reasonable assurance of the safety and effectiveness of the device for its intended use.

REPORTING UNDER THE MEDICAL DEVICE REPORTING (MDR) REGULATION. The Medical Device Reporting (MDR) Regulation became effective on December 13, 1984. This regulation was replaced by the reporting requirements of the Safe Medical Devices Act of 1990 which became effective July 31, 1996 and requires that all manufacturers and importers of medical devices, including in vitro diagnostic devices, report to the FDA whenever they receive or otherwise become aware of information, from any source, that reasonably suggests that a device marketed by the manufacturer or importer:

(1)May have caused or contributed to a death or serious injury; or

(2)Has malfunctioned and such device or similar device marketed by the manufacturer or importer would be likely to cause or contribute to a death or serious injury if the malfunction were to recur.

The same events subject to reporting under the MDR Regulation may also be subject to the above "Adverse Reaction and Device Defect Reporting" requirements in the "Conditions of Approval" for this PMA. FDA has determined that such duplicative reporting is unnecessary. Whenever an event involving a device is subject to reporting under both the MDR Regulation and the "Conditions of Approval" for a PMA, the manufacturer shall submit the appropriate reports required by the MDR Regulation within the time frames as identified in 21 CFR 803.10(c) using FDA Form 3500A, i.e., 30 days after becoming aware of a reportable death, serious injury, or malfunction as described in 21 CFR 803.50 and 21 CFR 803.52 and 5 days after becoming aware that a reportable MDR event requires remedial action to prevent an unreasonable risk of substantial harm to the public health. The manufacturer is responsible for submitting a baseline report on FDA Form 3417 for a device when the device model is first reported under 21 CFR 803.50. This baseline report is to include the PMA reference number. Any written report and its envelope is to be specifically identified, e.g., "Manufacturer Report," "5-Day Report," "Baseline Report," etc. Any written report is to be submitted to:

Food and Drug Administration
Center for Devices and Radiological Health
Medical Device Reporting
PO Box 3002
Rockville, Maryland 20847-3002

Copies of the MDR Regulation (FOD # 336&1336)and FDA publications entitled "An Overview of the Medical Device Reporting Regulation" (FOD # 509) and "Medical Device Reporting for Manufacturers" (FOD #987) are available on the CDRH WWW

Home Page. They are also available through CDRH's Fact-On-Demand (F-O-D) at 800-899-0381. Written requests for information can be made by sending a facsimile to CDRH's Division of Small Manufacturers Assistance (DSMA) at 301-443-8818.

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David C. Gakenhaimer, Ph.D.
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SEP 30 1998

Re: P980025
Logicon Caries Detector™
Filed: June 18, 1998
Amended: July 27, August 7 and September 8, 1998

Dear Dr. Gakenheimer:

The Center for Devices and Radiological Health (CDRH) of the Food and Drug Administration (FDA) completed its evaluation of your premarket approval application (PMA) for the Logicon Caries Detector™. We notified you that the application was approved by an approval order dated, September 25, 1998. The following sentence:

> It is intended as an adjunct designed to work in conjunction with existing Trextrophy RVG digital x-ray radiographic system with TWI Software Version 3.0 or higher.

was incorrect. The sentence is corrected as follows:

> It is intended as an adjunct designed to work in conjunction with existing TrexTrophy RVG digital x-ray radiographic system with TWI Software Version 3.0 or higher.

We hope that this correction has not inconvenienced you. If you have any questions about this corrective action, please contact me at 301 594-2186.

Sincerely yours,

Kathy Poneleit
Director, Premarket Approval Program
Office of Device Evaluation
Center for Devices and
Radiological Health

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SUMMARY OF SAFETY AND EFFECTIVENESS DATA

I. GENERAL INFORMATION

Device Generic Name: Dental X-Ray Image analysis software

Device Trade Name: Logicon Caries Detector™

Name of Applicant: Logicon RDA, a Northrop Grumman Company
6053 West Century Boulevard
Los Angeles CA 90045

Date of Panel Recommendation: August 17, 1998

Premarket Approval Application (PMA) Number: P980025

Date of Notice of Approval to Applicant: SEP 25 1998

II. INDICATIONS FOR USE

The Logicon Caries Detector™ is a software decision aid for the diagnosis of caries that have penetrated into the dentin, on unrestored proximal surfaces of secondary dentition, through the analysis of digital intra-oral radiographic imagery. It is intended as an adjunct designed to work in conjunction with an existing TrexTrophy RVG digital x-ray radiographic system with TWI Software Version 3.0 or higher.

III. DEVICE DESCRIPTION

Logicon Caries Detector™ is an image analysis computer software tool designed to assist the dentist in locating and classifying proximal surface caries in digital intra-oral radiographs. It analyzes digital x-ray images acquired by a commercially available digital x-ray sensor system called RVG that is manufactured by Trophy Radiologie of Croissy-Beaubourg, France, a subsidiary of Trex Medical Corporation. The device includes: 1) a CD with the executable program, tutorial presentation, demonstration images, and results of analyses of the demonstration images; and 2) a software box with hardcopies of the *User Guide*, tutorial presentation, Labeling, installation instructions and user authorization forms. Logicon Caries Detector™ is designed to perform its analytic calculations within less than 10 seconds on a Pentium class PC. The graphical interface displays an enlarged image of the radiograph being analyzed (with an outline of the potential lesion site shown on the image) along with two plots displaying tooth density and probability information associated with a potential lesion found by the software.

Using proprietary directional gradient filters, the program automatically finds the outer edge of the tooth and the boundary between the enamel and dentin and highlights these boundaries on the x-ray image for the user's review and approval. The *User Guide* warns the user to be cautious of results if the program is unable to successfully find these boundaries.

The program then analyzes the x-ray (thus tooth) density along contour lines in the enamel and adjacent dentin for the presence of local radiolucencies (local dark regions in the x-ray). These indicate tooth mineral loss. These radiolucent features are outlined on the x-ray image. The features presented on the radiograph can then be toggled on and off to allow an unobscured view and confirmation of the features found.

A mathematical plot of these local radiolucencies is also displayed on a separate window labeled 'Tooth Density' next to the x-ray image. This plot is intended to show the user all local radiolucencies. To avoid an overcrowded picture, only the most obvious local radiolucencies are shown on the x-ray image itself. The density variation plot provides the user with additional information that can be helpful in his/her diagnosis.

The program then extracts density and spatial information about the most obvious local radiolucencies for use in lesion classification. These features include the magnitude of the feature (darkness), area of the feature, depth of penetration of the feature, and the alignment of the feature in the enamel and in the dentin (if the feature extends into the dentin).

Then, using advanced mathematical methods, the program compares the features in the current x-ray image with those in a database of 608 images of teeth with lesions present at a range of depths seen in normal practice. The database was developed at the UCLA School of Dentistry using extracted teeth which were x-rayed and then histologically sectioned to determine the true lesion status. The outputs of this step of the program are the probabilities of having a lesion in the enamel and separately in the dentin.

The probabilities of a lesion in the enamel and in the dentin are presented in a third window labeled 'Lesion Probability' in the form of bar graphs. Also shown on these bar graphs are decision thresholds (yellow horizontal lines) as decision aids. When the probability bar is well above the decision threshold for a lesion in the dentin, the dentist is advised to consider restorative treatment of the tooth. On the other hand, if the probability bar for a dentin lesion is near or below the decision threshold, the dentist is advised to wait and re-evaluate the case at a later date.

III. CONTRAINDICATIONS, WARNINGS, AND PRECAUTIONS

CONTRAINDICATIONS: None

WARNINGS

The detection algorithms used by Logicon Caries Detector™ are based on laboratory data for unrestored proximal surfaces of adult dentition and the results for primary dentition, occlusal surfaces or surfaces with existing restorations could be misleading.

PRECAUTIONS

Do not analyze improperly exposed radiographs (either underexposed or overexposed).

Avoid analyzing overlapping proximal contacts.

Designate the proximal surface of interest carefully to avoid extraneous radiolucencies near the occlusal surface and the cemento-enamel junction (CEJ).

Verify that the tooth edge and dentino-enamel junction (DEJ) have been found correctly.

Rerun the program or trace the boundaries using the manual option if the tooth edge or DEJ are not found correctly.

IV. ALTERNATE PRACTICES OR PROCEDURES

The conventional procedure for the diagnosis of proximal surface caries in the case where the contact of adjacent surfaces precludes direct physical

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examination, is through the visual examination of intra-oral radiographs and subsequent clinical judgment by a trained clinician (i.e., a dentist).

V. MARKETING HISTORY

Sales of Logicon Caries Detector™ began overseas in September 1997. A total of 93 copies of the software device have been sold through June 8, 1998, in Europe (Germany, UK, Spain, Portugal, Italy, Poland, and Lithuania), Asia (Japan), and South America (Chile and Brazil). The firm received the CE mark on June 24, 1998. The device has not been withdrawn from marketing in any country for any reason related to safety and effectiveness.

VII. POTENTIAL ADVERSE EFFECTS OF DEVICE ON HEALTH

While there are no direct adverse effects associated with this software program, the risks associated with an error in the operation of Logicon Caries Detector™ are the same as those associated with the human clinician misdiagnosing dental caries. Specifically, these are the effects associated with the false identification of a tooth requiring restoration and the false identification of a tooth as not requiring restoration. If the dentist decides to restore a tooth when it is not needed, then he/she subjects the patient to the usual risks associated with the restoration process. These include discomfort to the patient, risk of recurrent decay due to failure of the restoration, and adverse drug reaction to anesthetic

If the dentist decides not to restore a tooth when it is required, then he/she subjects the patient to the usual risks associated with a non-treatment of an active lesion. These include the consequences of advanced dental decay and possible pulpitis and dental abscess. These conditions would require more aggressive treatments than would have been required with earlier diagnosis. Such treatments may include root canal therapy or extraction of the tooth.

VIII. SUMMARY OF PRECLINICAL STUDIES

Extracted Tooth Laboratory Study

1. Background

A laboratory study was conducted to initially demonstrate the performance of Logicon Caries Detector without the involvement of patients. This study was conducted as part of the development of the device. A database of 608 images of extracted teeth with a range of caries problems was developed at the UCLA School of Dentistry. The database was divided into two parts. One part (consisting of 288 images) was used to train a neural network to predict the presence of caries. The second part of the database (consisting of 320 images) was used to test the neural network and compare the performance of the neural network with that of a team of dentists who visually diagnosed the same 320 images without the help of Logicon Dental Caries Detector.

The following is a summary of the laboratory study which demonstrated the capability of Logicon Caries Detector to significantly improve diagnostic accuracy as compared to human visual examination alone in a controlled laboratory setting involving extracted teeth.

2. Laboratory Study Objectives

a) To measure the efficacy of Logicon Caries Detector™ in the detection of lesions penetrating into the dentin as compared to human experts (dentists),

b) To measure the efficacy of Logicon Caries Detector™ in the detection of enamel lesions as compared to human experts (dentists).

3. Methods and Materials

a) A set of digital x-ray images of proximal tooth surfaces was collected for which the true lesion status was known. The abilities of humans and Logicon Caries Detector™ in detecting dental caries were tested on this set of images. Extracted teeth were mounted in a fashion simulating natural tooth contact. X-ray images of the mounted teeth were then taken using a CCD based imaging sensor. The teeth were then cross-sectioned and examined under a 20X microscope to determine the true presence and depth of penetration of caries.

b) A total of 608 surfaces divided among the four tooth types (molars, premolars, canines and incisors) and four levels of lesion severity (caries free surface, lesion confined to outer half of enamel, lesion penetrating more than half way through the enamel, and lesion penetrating less then half way through the dentin) were studied. Of these surfaces, 288 were used in development of the software (training a neural network) and the remaining 320 surfaces were used to independently test the software.

b) A panel of 11 dentists on the faculty of the University of California at Los Angeles (UCLA) School of Dentistry were presented the 320 x-ray images used for testing the software on a 14i SVGA computer monitor in random order with respect to tooth type and lesion severity. The dentists were asked to grade the image of each proximal tooth surface for the presence of a carious lesion penetrating into the dentin. Dentin penetration is significant because in the case of proximal surfaces where direct visual and physical exam (probing with a sharp instrument) is impossible, radiographic evidence of dentin penetration is the main criteria for the decision to treat the tooth.

To allow for dentist uncertainty and the later construction of ROC (receiver operating characteristic) curves, the dentists were allowed one of five levels of certainty in their evaluation: "definitely yes", "probably yes", "do not know", "probably no', and "definitely no".

The same surfaces were analyzed by Logicon Caries Detector™, which was operated by the principal investigator. For each surface Logicon Caries Detector™ computed the probability of a carious lesion being present in the dentin. ROC curves were generated by varying a decision threshold for this probability (surface scored as carious if the probability is above the decision threshold). These ROC curves were then compared to those produced from data generated by the dentists diagnosing the presence of lesions in the dentin.

c) The dentists were also asked to score each surface for the presence of any lesion, again, using the same five point confidence scale. (Note, this is equivalent to scoring the presence of an enamel lesion because proximal surface caries start in the enamel and then may progress to the dentin. Therefore, a surface with any lesion must at least have a lesion in the enamel.)

Then similar to the case for dentin lesion, the same surfaces were analyzed by Logicon Caries Detector™, which computed the probability of enamel lesions being present. Again, ROC curves were generated for performance in the diagnosis of enamel lesions and these were compared to those produced from data generated by the dentists in diagnosing any (enamel) lesion.

4. Results

ROC analysis is a commonly used method for assessing the performance of classification algorithms because a single curve shows the tradeoff between false positive and true positive identification parametrically as a function of decision threshold. In general, the higher the curve or the greater the area under the curve, the greater the overall accuracy.

a) Figure 1a to Figure 1d compares the ROC curves between dentists and Logicon Caries Detector™ for **dentin** lesion identification for all four tooth types. The 95 percent confidence region (two standard errors) in the mean of the dentists' responses is indicated by the gray region and was calculated by covariance analysis. Table 1a shows the difference in **dentin** lesion identification using a decision threshold corresponding to a 15 percent false positive identification rate (roughly, the point of highest overall accuracy for the data in this study).

b) Similar to the above, Figure 1e to Figure 1h compares the ROC curves between dentists and Logicon Caries Detector™ for **enamel** lesion identification for all four tooth types. The gray region indicates the 95 percent confidence region. Table 1b shows the difference in **enamel** lesion identification using a decision threshold corresponding to a 15 percent false positive identification rate.

5. Conclusions

The performance of Logicon Caries Detector™ is equal to or better than dentists in the detection of dentinal lesions. It exceeds by two standard errors the dentists' responses over most of the range of the ROC curves for all four tooth types, and at the 15 percent false positive identification level, it exceeds the average response of the dentists by 8 to 32 percent depending upon tooth type.

The performance of Logicon Caries Detector™ is not significantly different from dentists in the detection of enamel lesions. This is may be due to the difficulty of detecting early lesions confined to the enamel.

the same lesion data as for the test surface. For validation purposes, intra-oral camera images of all prepared and exposed surfaces were taken and included with tabulated data.

d) Endpoint of Study:

The endpoint of the study for each individual tooth surface was either the completion of the final restoration (e.g., amalgam restoration, crown, composite, etc.) for that surface or the decision by the dentist not to restore the tooth because of lack of caries in the dentin. The determination of caries status for each surface was made once, and it was not the intention of this study to follow a given tooth surface over time given the time and practical constraints of conducting a study in a normal private practice setting. Thus, the scope of this study was confined to an cross sectional assessment of the dentists' performance using Logicon Caries Detector™ at a given point in time.

e) Sample Size

To estimate the number of dentists and surfaces required, preliminary results from seven or eight dentists were analyzed. These dentists looked at roughly 10 surfaces each with an average improvement in diagnostic accuracy of approximately 20 percent and standard deviation of approximately 35 percent. Assuming similar results from additional dentists analyzing 10 surfaces each and assuming a t-distribution for the difference between means (see Dixon and Massey, 4th Edition, Sec. 8-5), an estimated sample size of approximately ten dentists analyzing at least 10 surfaces each would be required to establish significance at the 5 percent level (p=0.05). Ultimately valid data on 175 surfaces from 18 dentists analyzing an average of 9.7 surfaces each were **actually** acquired.

4. Demographic Data

The demographic data for the clinical study are summarized in Table 2 (a, b, c, d). Table 2a shows the number of study sites and the distribution of patients and tooth surfaces analyzed by state. Geographic location may have some influence on the mineral content of teeth in the local population due to variations in local diet and mineral content of the water supply. The relatively large number and range of locations of study sites throughout the Eastern and Western United States provides sufficient variability due to geographic location.

The distribution of tooth surfaces in the study by age of patients is given in Table 2b. The distribution does not appear biased with respect to the age distribution for the U.S. population. There is a weak correlation between tooth mineral content and age. Specifically, newly erupted teeth tend to have slightly lower surface enamel mineral content, with negligible difference within a year after eruption. But again, there is no evidence that the delectability of caries is age dependent. No restrictions were placed on selection of patients by age other than to restrict to selection to permanent or adult dentition.

The distribution of tooth surfaces in the study by race of patients is given in Table 2c. There is no evidence that the delectability of dental caries is race dependent.

Table 2a. ††Distribution of dentists and patients by geographical region in clinical study.

Region (State)	Number of Study	Number of	Number of Surfaces From

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	Sites	Patients	Each Region
California	7	32	61
Utah	1	8	19
Idaho	1	3	5
Washington State	3	24	42
North Carolina	4	18	39
Georgia	1	2	3
New York	1	3	6
Total	18	90	175

Table 2b. ††Distribution of patients by age in clinical study.

Age Group	Number of Patients	Number of Surfaces
10-19	12	29
19-29	20	47
30-39	23	40
40-49	18	32
50-59	6	11
60-69	5	9
70-79	3	5
>80	0	0
Unreported	2	2

Table 2c. ††Distribution of patients by race in clinical study.

Race	Number of Patients	Number of Surfaces
Caucasian	68	130
Black	2	4
Hispanic	3	5
Asian	2	5
Other or Unreported	15	31

Table 2d. ††Distribution of patients by gender in clinical study.

Gender	Number of Patients	Number of Surfaces
Male	41	85
Female	48	90

5. Gender Bias

The demographics relating to gender distribution are shown in Table 2d. The number of tooth surfaces from females (90) and from males (85) are consistent with an equal distribution of the sexes in the general population. Furthermore, the number of tooth surfaces from females found to have caries penetrating the dentin (53) and the number of tooth surfaces from males found to have caries penetrating the dentin (55) are consistent with an equal incidence of dental caries with respect to sex for patients selected into the study

6. Data Analysis and Results

Data were obtained from 18 dentists with 106 patients in 16 private practice offices (including 3 dentists in the Faculty Group Practice at UCLA). This included a total of 175 valid proximal tooth surfaces assessed for the presence of lesions penetrating into the dentin. A total of 218 tooth surfaces were enrolled into the study but for 27 of these surfaces, the treatment was not completed because the patient did not return for treatment or the dentist was unable to schedule the patient for the study. An additional 16 surfaces were eliminated from the study because of deviation from the study protocol resulting in the absence of usable valid data.

Effectiveness was gauged by calculating three measures of performance for dentin caries diagnosis for each dentist both before and after running Logicon Caries Detector™. These were sensitivity, specificity and accuracy. Sensitivity, also referred to as the true positive identification rate or true positive, is the fraction of correct caries diagnoses made by a dentist (i.e., the number of surfaces with dentin caries correctly diagnosed divided by the total number of surfaces analyzed by the dentist which in fact have dentin caries). Specificity, also referred to as true negative, is the fraction of correct caries free diagnoses (i.e., the number of surfaces free of dentin caries correctly diagnosed divided by the total number of surfaces analyzed by the dentist which in fact are free of dentin caries). (Note: 1-sensitivity = false negative and 1-specificity = false positive.) Finally, accuracy is the

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fraction of all correct diagnoses made by a dentist (i.e. the number of surfaces with dentin caries correctly diagnosed plus the number of surfaces free of dentin caries correctly diagnosed divided by the total number of surfaces analyzed by the dentist).

Table 3a shows the diagnostic sensitivity of each dentist both before and after running Logicon Caries Detector™ as well as the difference in sensitivity. The mean sensitivity for all the dentists before running Logicon Caries Detector™ is 70.3 percent and afterwards is 90.5 percent with a difference of 20.3 percent. Considerable variation existed in the performance between dentists, but a strong trend towards improvement for most dentists was observed. To control for dentist variability, an unweighted-paired t-test was performed to determine whether the mean difference was significantly different from zero. Under the null hypothesis that the underlying true mean difference is zero, the computed two sided p value is p=0.0357. Thus, if the null hypothesis were true, we would observe a mean difference of 20.3 percent or greater less than 4 percent of the time.

Almost the same result for sensitivity was obtained using the Wilcoxon signed rank test where the null hypothesis is that the underlying true median difference is zero and p=0.0371, a significant improvement in diagnostic sensitivity associated with the use of Logicon Caries Detector™.

Summary results for specificity is shown in Table 3b. The average (mean) specificity for all dentists before running Logicon Caries Detector™ is 88.6 percent and afterwards is 88.3 percent with a difference of -0.3 percent. Under the null hypothesis, the observed mean difference has a p value of p=0.754 (based on the paired t-test) and the observed medium difference has a p value of p=0.99 (based on the Wilcoxon test). Thus, no change in diagnostic specificity was observed.

Table 3c shows results for the diagnostic accuracy of each dentist both before and after running Logicon Caries Detector™. The average (mean) accuracy for all dentists before running Logicon Caries Detector™ is 75.6 percent and afterwards is 88.3 percent with a difference of 12.8 percent. Under the null hypothesis, the observed mean difference has a p value of p=0.043 (based on the paired t-test) and the observed median difference has a p value of p=0.0537 (based on the Wilcoxon test). Thus, there is a significant improvement in diagnostic accuracy associated with the use of Logicon Caries Detector™. In view of the above, it is reasonable to conclude that the improvement in accuracy is due entirely to the improvement in sensitivity.

Three additional statistical analyses were conducted besides the two tests described above. These were: 1) a weighted paired t-test, where the weights were proportional to the number of surfaces each dentist evaluated, since all 18 dentists did not evaluate the same number of surfaces, 2) a McNemar procedure in a paired comparison with the performance on each tooth surface where the unit of analysis was tooth surface rather than the dentists overall performance, and 3) a logistic regression model to account for the fixed effect (in this case the treatment) of LogiconCaries Detector™ as well as the possible fixed effect of tooth type and the possible random effects of dentist or patient on diagnostic performance. The conclusions from these additional tests are the same as those in Tables†I-3†a, b, c, that is, there is a significant improvement in sensitivity and accuracy but no significant difference in specificity.

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Table 3a. Diagnostic sensitivity by dentist for the diagnoses of caries into the dentin on proximal surfaces before and after using Logicon Caries Detector™.

DENTIST	NUMBER OF SURFACES EXAMINED	SENSITIVITY OF INITIAL EXAMS	SENSITIVITY OF FINAL EXAMS	DIFFERENCE IN SENSITIVITY
AND	17	0.353	1.000	0.647
BAU	2	0.500	0.500	0.000
DON	14	0.571	1.000	0.429
GOL	2	1.000	1.000	0.000
HOR	1	0.000	1.000	1.000
HUY	9	0.778	0.889	0.111
LAB	3	0.667	0.667	0.000
LIN	1	1.000	1.000	0.000
MAG	5	0.000	1.000	1.000
MAL	2	1.000	1.000	0.000
OLS	11	1.000	1.000	0.000
ONT	6	1.000	1.000	0.000
RIC	4	0.750	1.000	0.250
SEL	6	1.000	0.833	-0.1667
STE	5	1.000	0.800	-0.200
VEN	7	0.714	0.857	0.143
VIC	0	.	.	.
WEI	13	0.615	0.846	0.231
Total	**108**			
MEAN		**0.703**	**0.905**	**0.203**
St. Dev.		0.336	0.144	0.364
St. Error of Mean		0.081	0.035	0.088

Tests for Significance

* H_0: **mean difference = 0, n=17: t=2.294, p = 0.0357 (< 4% chance, difference in means is significant)**

** H_0: **median difference = 0, n=17, signed rank = 20.5, p=0.0371 (< 4% chance, difference in medians is significant)**

* Based on unweighted paired t-test: Altman, D.G., *Practical Statistics for Medical Research*, Chapman & Hall, 1990.

** Based on Wilcoxon Ranked-Sum Test: Kurtz, T.E., *Basic Statistics*, Prentice-Hall, 1963.

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VIII. CONCLUSIONS DRAWN FROM THE STUDIES

1. Risk versus Benefit Analysis

The results of the clinical study demonstrated that dentists using Logicon Caries Detector™ improved their diagnoses of lesions penetrating into the dentin without degrading their diagnoses of lesions that do not penetrate the dentin and may not require treatment

2. Safety

Logicon Caries Detector™ poses no direct safety hazard to the patient because the product is data analysis software and therefore does not expose the patient to any drug or physical device. The possible indirect safety hazards would be those associated with the dentist incorrectly identifying a tooth surface as requiring restorative treatment as a result of using Logicon Caries Detector™. These are the usual safety hazards associated with dental restorative treatment. The results of the clinical study show that using Logicon Caries Detector™ along with conventional diagnostic methods does not result in an increase of tooth surfaces being incorrectly diagnosed as requiring restoration. Therefore, Logicon Caries Detector™ does not indirectly expose the patient to any greater safety hazard (due to unnecessary dental restorative treatment) than conventional diagnostic methods alone.

3. Effectiveness

The performance of dentists in this clinical study demonstrates that analyzing digital radiographic imagery with Logicon Caries Detector™ is effective in improving sensitivity and overall diagnostic accuracy in the detection of proximal lesions penetrating the dentin for adult dentition.

X. PANEL RECOMMENDATION

A meeting of the FDA Radiological Devices Panel took place on August 17, 1998 to review the sponsor's submission. The Panel recommended approval of the application.

XI. CDRH DECISION

CDRH concurred with the recommendation of the Panel. Based on the data submitted and the clinical results, CDRH approved the PMA for the stated indications on SEP 25 1998

The applicant's manufacturing and control facilities were inspected on September 3, 1998, and the facilities were found to be in compliance with the Good Manufacturing Practice (GMP) regulations.

XII. APPROVAL SPECIFICATIONS

Directions for use: See the labeling.

The sale, distribution, and use of this device are restricted to prescription use in accordance with 21 CFR 801.109 within the meaning of section 520(e) of the Federal Food, Drug, and Cosmetic Act (the act) under the authority of section 515(d)(1)(B)(ii) of the act.

Warnings, Hazards to Health from Use of the Device: See Indications, Contraindications, Warnings, Precautions and Adverse Reactions in the labeling.

XIII. REFERENCES:

Goaz, P.W. and White, S.C., Oral Radiology: Principals and Intrepretation, C.V. Mosby, 3rd Edition, 1994.

Altman, D.G., Practical Statistics for Medical Research, Chapman & Hall, 1990.

Kurtz, T.E., Basic Statistics, Prentice Hall, 1963.

A mathematical plot of these local radiolucencies is also displayed on a separate window labeled "Tooth Density' next to the x-ray image. This plot is intended to show the user all local radiolucencies. To avoid an overcrowded picture, only the most obvious local radiolucencies are shown on the x-ray image itself. The density variation plot provides the user with additional information that can be helpful in his/her diagnosis.

The program then extracts density and spatial information about the most obvious local radiolucencies for use in lesion classification, These features include the magnitude of the feature (darkness), area of the feature, depth of penetration of the feature, and the alignment of the feature in the enamel and in the dentin (if the feature extends into the dentin).

Then, using advanced mathematical methods, the program compares the features in the current x-ray image with those in a database of 608 images of teeth with lesions present at a range of depths seen in normal practice. The database was developed at the UCLA School of Dentistry using extracted teeth, which were x-rayed and then histologically sectioned to determine the true lesion status. The outputs of this step of the program are the probabilities of having a lesion in the enamel and separately in the dentin.

The probabilities of a lesion in the enamel and in the dentin are presented in a third window labeled 'Lesion Probability' in the form of bar graphs. Also shown on these bar graphs are decision thresholds (yellow horizontal lines) as decision aids. When the probability bar is well above the decision threshold for a lesion in the dentin, the dentist is advised to consider restorative treatment of the tooth. On the other hand, if the probability bar for a dentin lesion is near or below the decision threshold, the dentist is advised to wait and re-evaluate the case at a later date.

IV. CONTRAINDICATIONS, WARNINGS AND PRECAUTIONS

CONTRAINDICATIONS: None

WARNINGS

The detection algorithms used by Logicon Caries Detector' are based on laboratory data for unrestored proximal surfaces of adult dentition and the results for primary dentition, occlusal surfaces or surfaces with existing restorations could be misleading.

PRECAUTIONS

Do not analyze improperly exposed radiographs (either underexposed or overexposed).

Avoid analyzing overlapping proximal contacts.

Designate the proximal surface of interest carefully to avoid extraneous radiolucencies near the occlusal surface and the cemento-enamel junction (CEJ).

Verify that the tooth edge and dentino-enamel junction (DEJ) have been found correctly.

Rerun the program or trace the boundaries using the manual option if the tooth edge or DEJ are not found correctly.

V. ALTERNATE PRACTICES OR PROCEDURES

The conventional procedure for the diagnosis of proximal surface caries in the case where the contact of adjacent surfaces precludes direct physical

examination, is through the visual examination of intra-oral radiographs and subsequent clinical judgment by a trained clinician (i.e., a dentist).

VI MARKETING HISTORY

Sales of Logicon Caries Detector began overseas in September 1997. A total of 93 copies of the software device have been sold through June 8, 1998, in Europe (Germany, UK, Spain, Portugal, Italy, Poland, and Lithuania', Asia (Japan), and South America (Chile and Brazil). The firm received the CE mark on June 24, 1998. The device has not been withdrawn from marketing in any country for any reason related to safety and effectiveness.

VII. POTENTIAL ADVERSE EFFECTS OF DEVICE ON HEALTH

While there are no direct adverse effects associated with this software program, the risks associated with an error in the operation of Logicon Caries Detector" are the same as those associated with the human clinician misdiagnosing dental caries. Specifically, these are the effects associated with the false identification of a tooth requiring restoration and the false identification of a tooth as not requiring restoration. If the dentist decides to restore a tooth when it is not needed, then he/she subjects the patient to the usual risks associated with the restoration process. These include discomfort to the patient, risk of recurrent decay due to failure of the restoration, and adverse drug reaction to anesthetic.

If the dentist decides not to restore a tooth when it is required, then he/she subjects the patient to the usual risks associated with a non-treatment of an active lesion. These include the consequences of advanced dental decay and possible pulpitis and dental abscess. These conditions would require more aggressive treatments than would have been required with earlier diagnosis. Such treatments may include root canal therapy or extraction of the tooth.

VIII. SUMMARY OF PRECLINICAL STUDIES

Extracted Tooth Laboratory Study

1. Background

A laboratory study was conducted to initially demonstrate the performance of Logicon Caries Detector without the involvement of patients. This study was conducted as part of the development of the device. A database of 608 images of extracted teeth with a range of caries problems was developed at the UCLA School of Dentistry. The database was divided into two parts. One part (consisting of 288 images) was used to train a neural network to predict the presence of caries. The second part of the database (consisting of 320 images) was used to test the neural network and compare the performance of the neural network with that of a team of dentists who visually diagnosed the same 320 images without the help of Logicon Dental Caries Detector.

The following is a summary of the laboratory study which demonstrated the capability of Logicon Caries Detector to significantly improve diagnostic accuracy as compared to human visual examination alone in a controlled laboratory setting involving extracted teeth.

2. Laboratory Study Objectives

a) To measure the efficacy of Logicon Caries Detector@ in the detection of lesions penetrating into the dentin as compared to human experts (dentists),

b) To measure the efficacy of Logicon Caries Detector@ in the detection of enamel lesions as compared to human experts (dentists).

3. Methods and Materials

a) A set of digital x-ray images of proximal tooth surfaces was collected for which the true lesion status was known. The abilities of humans and Logicon Caries Detectorw in detecting dental caries were tested on this set of images. Extracted teeth were mounted in a fashion simulating natural tooth contact. X-ray images of the mounted teeth were then taken using a CCD based imaging sensor. The teeth were then cross-sectioned and examined under a 20X microscope to determine the true presence and depth of penetration of caries.

b) A total of 608 surfaces divided among the four tooth %types (molars, premolars, canines and incisors) and four levels of lesion severity (caries free surface, lesion confined to outer half of enamel, lesion penetrating more than half way through the enamel, and lesion penetrating less then half way through the dentin) were studied. Of these surfaces, 288 were used in development of the software (training a neural network) and the remaining 320 surfaces were used to independently test the software,

c) A panel of 11 dentists on the faculty of the University of California at Los Angeles (UCLA) School of Dentistry were presented the 320 x-ray images used for testing the software on a 14in SVGA computer monitor in random order with respect to tooth type and lesion severity. The dentists were asked to grade the image of each proximal tooth surface for the presence of a carious lesion penetrating into the dentin. Dentin penetration is significant because in the case of proximal surfaces where direct visual and physical exam (probing with a sharp instrument) is impossible, radiographic evidence of dentin penetration is the main criteria for the decision to treat the tooth.

To allow for dentist uncertainty and the later construction of ROC (receiver operating characteristic) curves, the dentists were allowed one of five levels of certainty in their evaluation: "definitely yes", "probably yes", "do not knows", Improbably no', and "definitely no".

The same surfaces were analyzed by Logicon Caries Detector™, which was operated by the principal investigator. For each surface Logicon Caries Detector computed the probability of a carious lesion being present in the dentin. ROC curves were generated by varying a decision threshold for this probability (surface scored as carious if the probability is above the decision threshold).

These ROC curves were then compared to those produced from data generated by the dentists diagnosing the presence of lesions in the dentin.

d) The dentists were also asked to score each surface for the presence of any lesion, again, using the same five-point confidence scale. (Note this is equivalent to scoring the presence of an enamel lesion because proximal surface caries start in the enamel and then may progress to the dentin. Therefore, a surface with any lesion must at least have a lesion in the enamel.)

Then similar to the case for dentin lesion, the same surfaces were analyzed by Logicon Caries Detector™, which computed the probability of enamel lesions being present. Again, ROC curves were generated for performance in the diagnosis of enamel lesions and these were compared to those produced from data generated by the dentists in diagnosing any (enamel' lesion.

4. Results

ROC analysis is a commonly used method for assessing the performance of classification algorithms because a single curve shows the tradeoff between false positive and true positive identification Parametrically as a function of decision threshold. In general, the higher the curve or the greater the area under the curve, the greater the overall accuracy.

a) Figure la to figure Id compares the ROC curves between dentists and Logicon Caries Detector™ for dentin lesion identification for all four-tooth types. The 95 percent confidence region (two standard errors) in the mean of the dentist's responses is indicated by the gray region and was calculated by covariance analysis. Table la shows the difference in dentin lesion identification using a decision threshold corresponding to a 15 percent false positive identification rate (roughly, the point of highest overall accuracy for the data in this study).

b) Similar to the above, Figure le to Figure lh compares the ROC curves between dentists and Logicon Caries Detector' for enamel lesion identification for all four tooth types. The gray region indicates the 95 percent confidence region. Table lb shows the difference in enamel lesion identification using a decision threshold corresponding to a 15 percent false positive identification rate.

5. Conclusions

The Performance of Logicon Caries Detector is equal to or better than dentists in the detection of dentinal lesions. It exceeds by two standard errors the dentists responses over most of the range of the ROC curves for all four tooth types, and at the 15 percent false positive identification level, it exceeds the average response of the dentists by 8 to 29 percent depending upon tooth type.

The performance of Logicon Caries Detector is not significantly different from dentists in the detection of enamel lesions. This may be due to the difficulty of detecting early lesions confined to the enamel.

Figure 1a. Comparison Between Logicon Caries Detector and Dentists: Molars - Dentinal Lesion

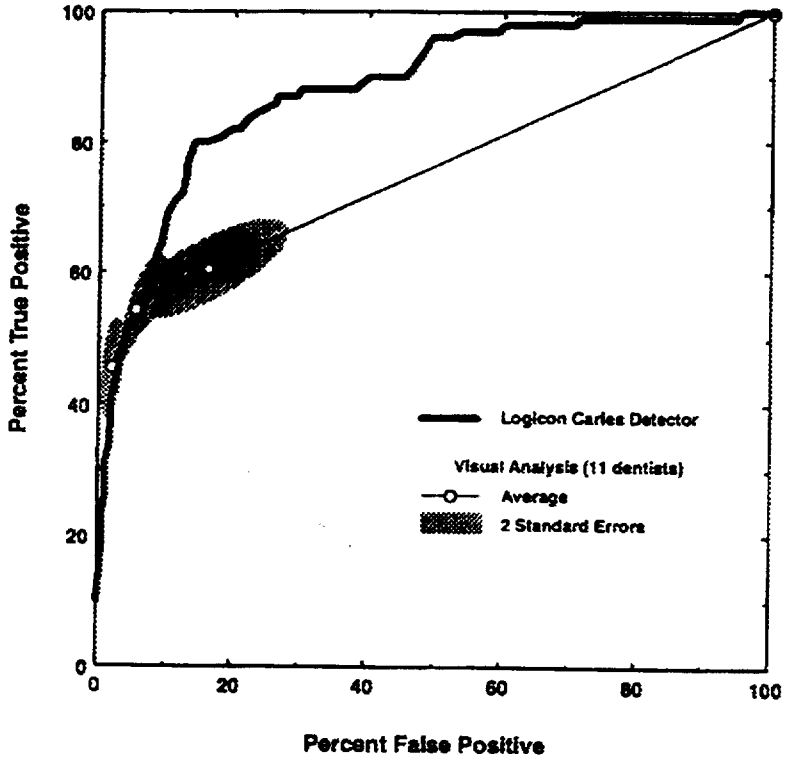

Figure 1b. Comparison Between Logicon Caries Detector and Dentists: Premolars - Dentinal Lesion

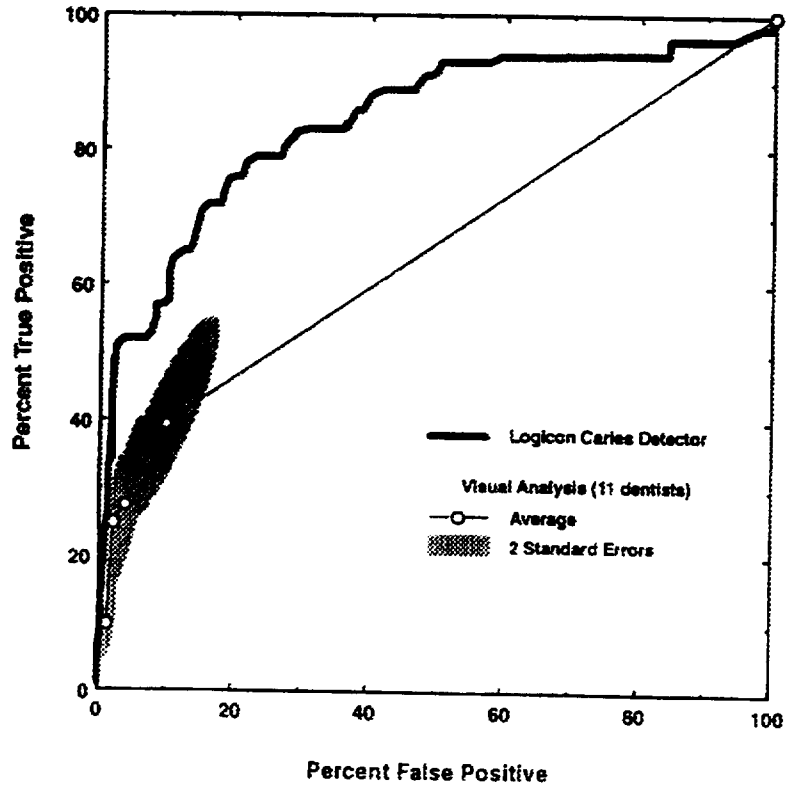

Figure 1c. Comparison Between Logicon Caries Detector and Dentists: Canines - Dentinal Lesion

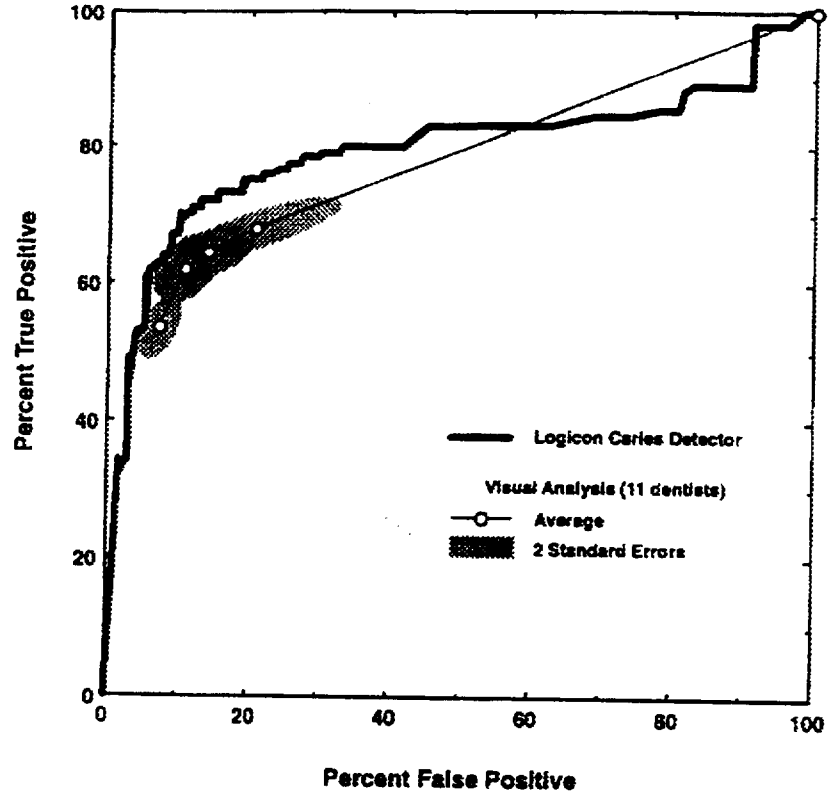

Figure 1d. Comparison Between Logicon Caries Detector and Dentists: Incisors - Dentinal Lesion

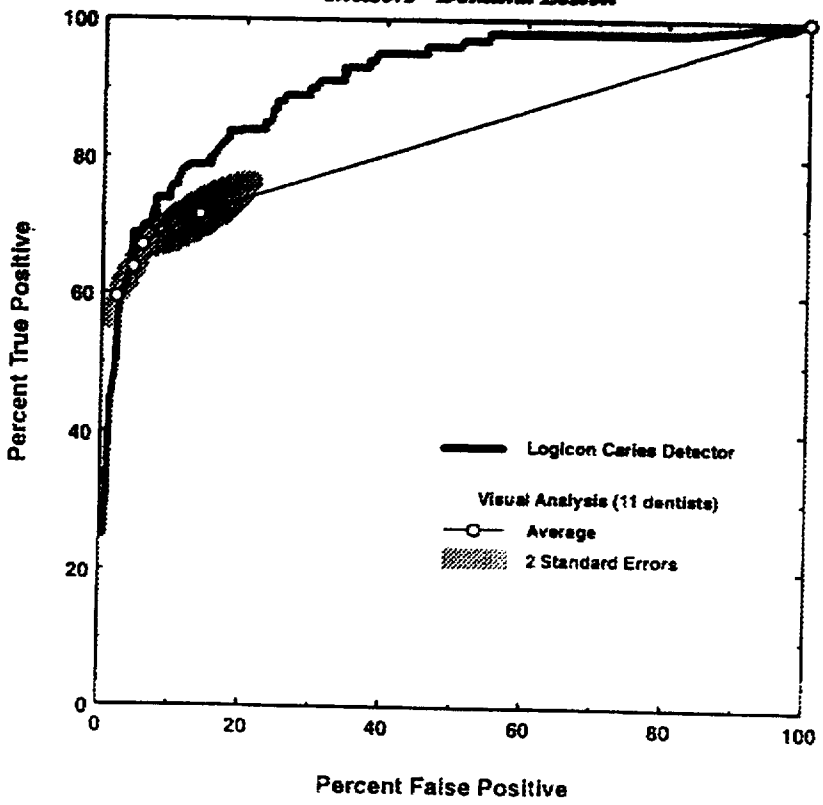

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Figure 1e. Comparison Between Logicon Caries Detector and Dentists: Molars - Enamel Lesion

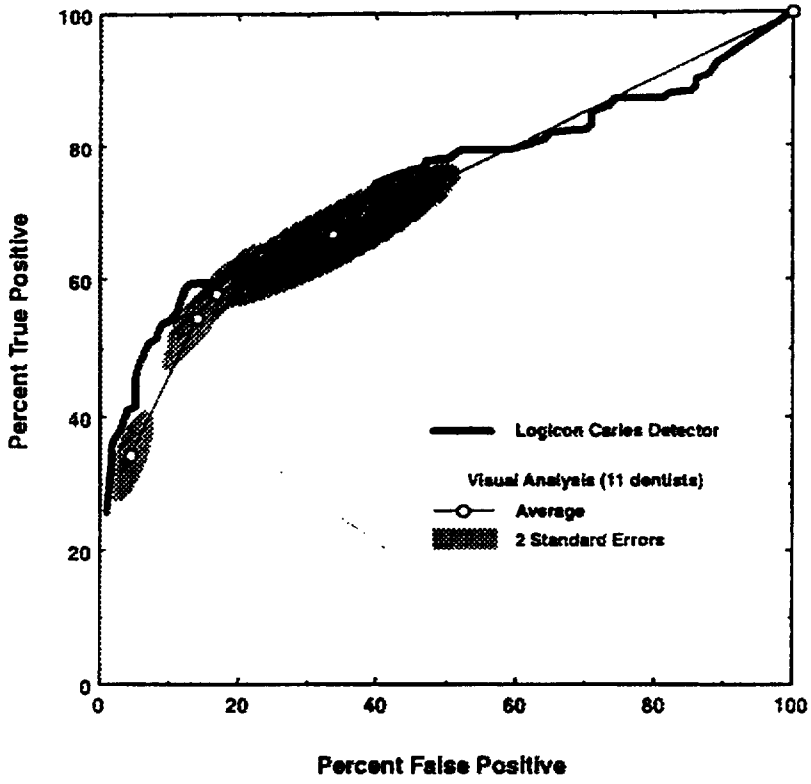

Figure 1f. Comparison Between Logicon Caries Detector and Dentists: Premolars - Enamel Lesion

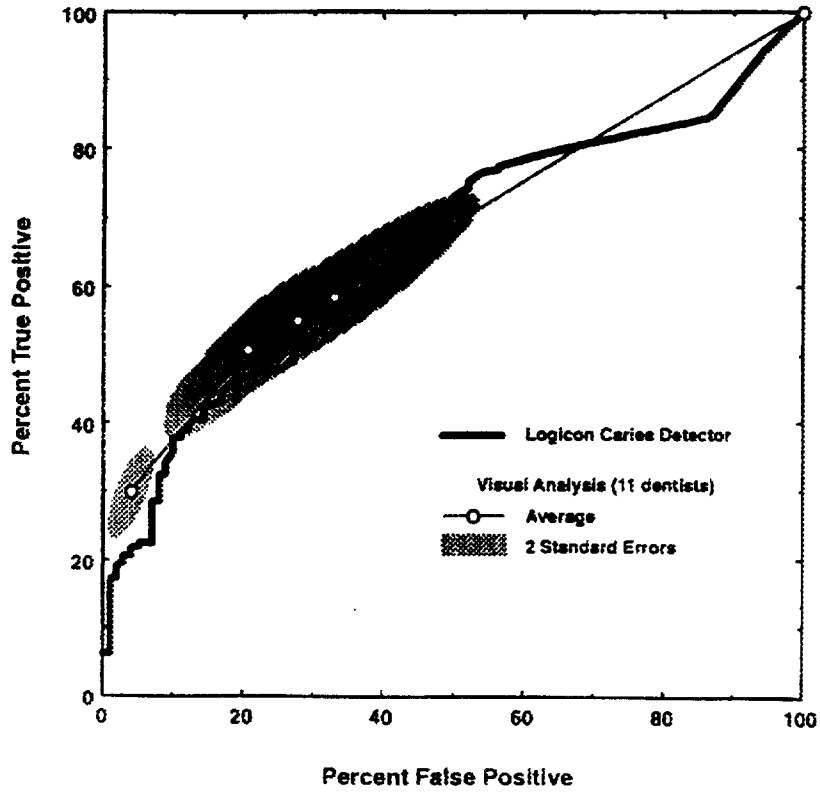

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Figure 1g. Comparison Between Logicon Caries Detector and Dentists: Canines - Enamel Lesion

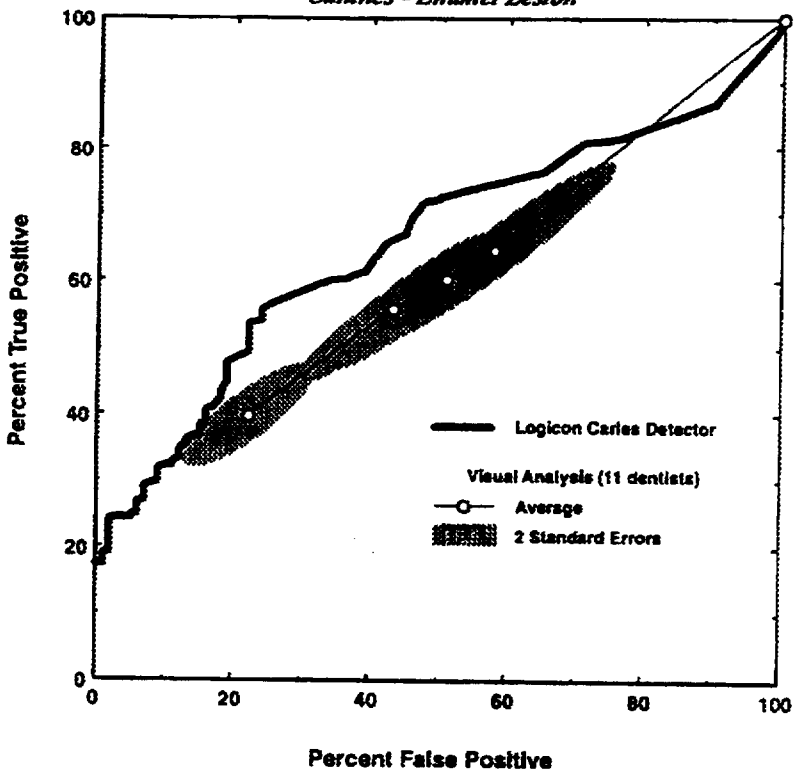

Figure 1h. Comparison Between Logicon Caries Detector and Dentists: Incisors - Enamel Lesion

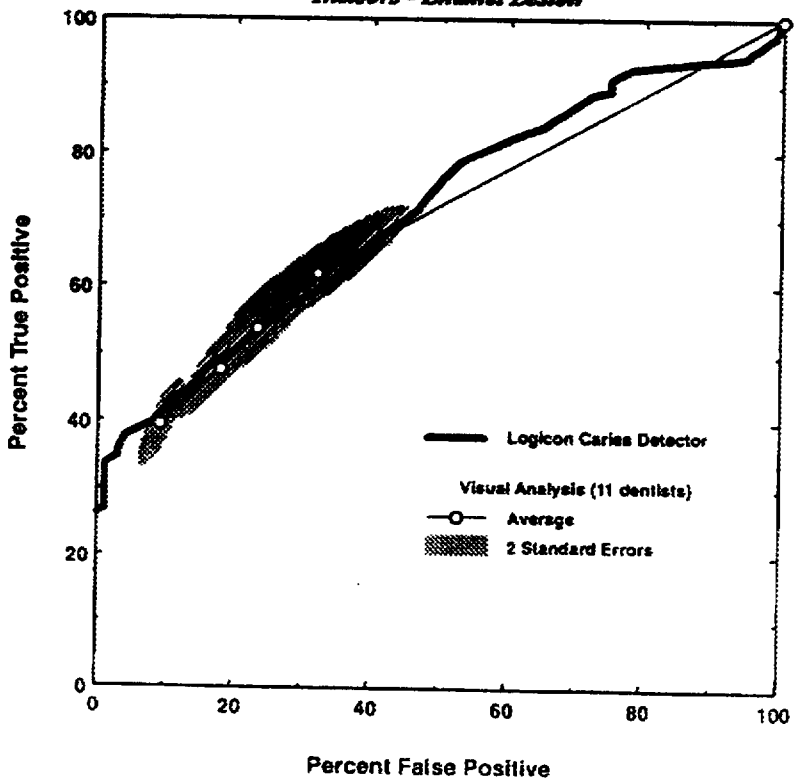

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Table 1a. Results of laboratory study comparing dentists and Logicon Caries Detector™ in the identification of proximal surface lesions penetrating into the dentin (read off point on ROC curve).

Tooth Type	True Positive Identification Rate (%)*		
	Dentists	Logicon Caries Detector	Difference
Molars	60	80	20
Premolars	43	72	29
Canines	64	72	8
Incisors	72	80	8

*Measured at 15% False Positive Identification Rate from ROC curves

Table 1b. Results of laboratory study comparing dentists and Logicon Caries Detector™ in the identification of enamel lesion on the proximal surface (read off point on ROC curve).

Tooth Type	True Positive Identification Rate (%)*		
	Dentists	Logicon Caries Detector	Difference
Molars	55	60	5
Premolars	44	43	-1
Canines	Out of range	38	NA
Incisors	44	45	1

*Measured at 15% False Positive Identification Rate from ROC curves

Software Verification & Validation Tests

As part of the software development process, four types of software verification and validation testing were performed:

a) Module level testing in-house
b) System level functional testing and performance evaluation in-house
c) Beta testing out-house (with dentists, outside of practice)
d) Clinical software testing out-house (with dentists as part of daily practice)

The module testing and system level functional testing of the software conducted in-house was successful. The results of the performance evaluation conducted in-house are described in the "Extracted Tooth Laboratory Study" discussion.

The beta testing conducted out-house with dentists (but outside their daily practices) provided important feedback on the user interface that was incorporated into the software design.

The software testing done as a part of the clinical study involved a pre-commercial version of the software (with a special data recording feature for the clinical study records). The software performance met all requirements and specifications. No complaints concerning the software performance were received from the dentists involved in the clinical study. The only request from the dentists was for a copy of the commercial version of the software built to be fully integrated with Trophy's latest version of the RVG x-ray image acquisition and storage software (Trophy's Windows Imaging Software Version 3.0 and higher).

Neural Network Training

As described above, the software uses neural networks that were trained using a database with known lesions, which were appropriately divided into a subset used for training and another subset used for verification of the performance of the trained network. The general nature of the features extracted and the general form of the neural network is described, but specific details are not given. Since the performance of such a system is not amenable to analytic verification, no specific neural network details are required. Instead, the performance of such a system would be verified empirically.

VIII. SUMMARY OF CLINICAL STUDY

1. Objective

The object of the study was to determine whether the addition of the Logicon device to dental practice increased the sensitivity and specificity of dental caries detection.

2. Study Design

The study was an open-label, multi-site trial, using standard x-ray as control designed to measure the change in each dentist's diagnostic performance due to Logicon Caries Detector™ under the normal clinical operating environment of private practices. **Truth was defined as the dentist's clinical assessment of the exposed lesion prior to restoration.**

a. Scope
- 18 private practice dentists
- 90 patients
- 175 surfaces examined

b) Dentist Selection/Training
- Dentists with experience with computers and Trophy RVG digital x-ray system
- Dentists trained in use of Logicon Caries Detector™
- Dentists tested on interpretation of standard image set (lesion status known)

c) Patient Case Selection Criteria
- Candidate surfaces: proximal surfaces, adult dentition of all 4 tooth types
- Criteria for test surfaces (i.e., surfaces with potential lesions)
  - Incipient enamel to moderate dentin lesions (excluding obvious lesions greater than halfway through the dentin)
  - Surfaces selected on "first come, first serve" basis
- Criteria for control surfaces (i.e., surfaces initially interpreted to be caries free)
  - Surface adjacent to test surface
  - Available to direct examination (visually and with probe)

d) Data Collection Process
- Dentist performed initial evaluation of test and control surfaces, visually only
- Dentist applied Logicon Caries Detector™ to images of both surfaces
- Dentist treated test surface and recorded lesion depth and takes video picture
- For control surfaces, dentist verified absence of lesion by direct examination (i.e., visual exam and probing) during preparation of test surface; if lesion was found, depth was determined as above
- Dentist completed Check List/Data Sheet with results of each step
- Data sheets returned to Logicon as collected for review

3. Detailed Description of Study Protocol

a) Dentist Selection and Training:

Dentists were selected from throughout the Eastern and Western United States. These included dentists in private practice and dentists in the faculty group practice at UCLA. All the dentists selected had some experience with computers, and all the dentists in private practice had experience with the digital radiographic system used in the study (the Trophy Radiology RVG System).

Dentists were trained in person in the use of Logicon Caries Detector™, including how to select the correct anatomic region of the tooth for analysis and how to interpret the highlighted features displayed on the x-ray image, density variation plots and probability bar graphs. Dentists were asked to interpret a set of standard images (where lesion status was known), and they were accepted into the study only after proficiency was demonstrated.

Dentists were shown 20 to 30 examples of incipient to moderate lesions as defined in a well-known text on dental radiology[1]. All dentists agreed on the radiographic criteria for proximal caries including the presence of the typical "double triangle" radiolucent pattern. Dentists did vary considerably in their judgment whether or not to treat in the samples

[1] Goaz, P.W. and White, S.C., *Oral Radiology: Principles and Interpretation*, C.V. Mosby, 3rd Edition, 1994.

shown, but this did not affect the dentist selection process to avoid biasing the study.

b) Patient Inclusion Criteria:

In selecting teeth for analysis, dentists were asked to place no restriction on tooth type (i.e., molar, premolar, canine or incisor). But in accordance with the proposed Indications for Use, dentists were asked to include only proximal surfaces (i.e., the surfaces between adjacent teeth) on adult dentition (permanent teeth in children were allowed) where no previous restoration had been placed.

Dentists were asked to select surfaces potentially requiring restorative treatment on a first come, first serve basis, to avoid biasing toward any sub-class of patients or tooth surfaces. Specifically, they were told to include cases ranging from incipient caries (i.e., less than halfway into the enamel) to moderate caries (less than halfway penetrating into the dentin toward the pulp). This selection was to be made subject to the above restriction and before running Logicon Caries Detector™ to avoid bias by the software. Dentists were asked to exclude obvious cases of dental caries where the lesion was readily seen radiographically to penetrate more than halfway through the dentin. The surfaces thus identified were termed "test surfaces".

In addition, whenever possible, dentists were asked to include a "control surface". These were surfaces initially interpreted (i.e., before analyzing with Logicon Caries Detector™) to be caries free and which would be exposed to direct visual and physical examination if the test surface was prepared for a restoration. Typically these would include the surface adjacent to test surface. This is not a "control" in the true sense as in a drug efficacy study but rather was intended as a means of testing the ability of Logicon Caries Detector™ to also correctly identify a caries free surface.

c) Test and Evaluation Conditions and Data Collection:

The study was performed in a clinical setting with dentists following their normal procedures with the following exceptions: 1) informed consent of patient to participate in this study, 2) for dentists in the UCLA faculty group practice, a digital radiograph (**used only for the study**) was taken in addition to a standard film radiograph **which was required for patient** records.

The dentist performed an initial evaluation of test and control surfaces without Logicon Caries Detector™. This included a diagnosis for the presence of a lesion in the enamel and the dentin, and an initial judgment to treat or not to treat. The dentist then applied Logicon Caries Detector™ to radiographic images of both test and control surfaces and performed a second evaluation of these surfaces. Treatment was based on this second evaluation. If a surface was not treated, then this surface and the associated control surface were not included in the study.

If a test surface was treated, then its true lesion status could be determined during cavity preparation. The dentist was asked to carefully note and record the percent penetration of the lesion into the enamel and the millimeters penetration into the dentin. The control surface exposed during the preparation of the test surface was assessed to be caries free if it exhibited no signs of cavitation or surface demineralization as indicated by a "catch" with a dental explorer. (However, without preparing this surface, one cannot exclude the possibility of subsurface demineralization.) If a control surface showed signs of cavitation and the dentist chose to restore the surface, then the dentist was asked to record

b) Dentist Selection/Training

c) Dentists with experience with computers and Trophy RVG digital x-ray System,
Dentists trained in use of. Logicon Caries Detectors'
Dentists tested on interpretation of standard image set (lesion status known)

c) Patient Case Selection Criteria
- Candidate surfaces: proximal surfaces, adult dentition of all 4 tooth types
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  Surfaces selected on "first come, first serve" basis
  Criteria for control surfaces (i.e., surfaces initially interpreted to be caries free)
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Dentist applied Logicon Caries Detector™ images of both surfaces Dentist treated test surface and recorded lesion depth and takes video picture For control surfaces, dentist verified absence of lesion by direct examination (i.e., visual exam and probing) during preparation of test surface; if lesion was found, depth was determined as above Dentist completed Check. List/Data Sheet with results of each step Data sheets returned to Logicon as collected for review

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Dentists were selected from throughout the Eastern and Western United States. These included dentists in private practice and dentists in the faculty group practice at UCLA. All the dentists selected had some experience with computers and all the dentists in private practice had experience with the digital radiographic system used in the study (the Trophy Radiology RVG System).

Dentists were trained in person in the use Logicon Caries Detector™ including how to select the correct anatomic region of the tooth for analysis and how to interpret the highlighted features displayed on the x-ray image, density variation plots and probability bar graphs, Dentists were asked to interpret a set of standard Images (where lesion status was known), and they were accepted into the study only after proficiency was demonstrated.

Dentists were shown 20 to 30 examples of incipient to moderate lesions as defined in a well-known text on dental radiology'. All dentists agreed on the radiographic criteria for proximal caries including the presence of the typical "double triangle" radiolucent pattern. Dentists did vary considerably in their Judgment whether or not to treat in the samples shown, but this did not affect the dentist selection process to avoid biasing the study.

'Goaz, P.W. and White, S.C., Oral Radiology: Principles and Interpretation, CV. Mosby, 3" Edition, 1994.

b) Patient Inclusion Criteria:

In selecting teeth for analysis, dentists were asked to place no restriction on tooth type (i.e., molar, premolar, canine or incisor). But in accordance with the proposed indications for Use, dentists were asked to include only proximal surfaces (i.e., the surfaces between adjacent teeth) on adult dentition (permanent teeth in children were allowed) where no previous restoration had been placed.

Dentists were asked to select surfaces potentially requiring restorative treatment on a first come, first serve basis. To avoid biasing toward any sub-class of patients or tooth surfaces. Specifically, they were told to include cases ranging from incipient caries (i.e., less than halfway into the enamel) to moderate caries (less than halfway penetrating into the dentin toward the pulp), This selection was to be made subject to the above restriction and before running Logicon Caries Detector" to avoid bias by the software. Dentists were asked to exclude obvious cases of dental caries where the lesion was readily seen radiographically to penetrate more than halfway through the dentin. The surfaces thus identified were termed "test surfaces".

I addition, whenever possible, dentists were asked to include a "control surface". These were surfaces initially interpreted (i.e., before analyzing with Logicon Caries Detector™ to be caries free and which would be exposed to direct visual and physical examination if the test surface was prepared for a restoration. Typically these would include the surface adjacent to test surface. This is not a "control" in the true sense as in a drug efficacy study but rather was intended as a means of testing the ability of Logicon Caries Detector™ also correctly identify a caries free surface.

c) Test and Evaluation Conditions and Data Collection:

The study was performed in a clinical setting with dentists following their normal procedures with the following exceptions: 1) informed consent of patient to participate in this study, 2) for dentists in the UCLA faculty group practice, a digital radiograph (used only for the study) was taken in addition to a standard film radiograph which was required for patient records.

The dentist performed an initial evaluation of test and control surfaces without Logicon Caries Detector™. This included a diagnosis for the presence of a lesion in the enamel and the dentin, and an initial judgment to treat or nor. to treat. The dentist then applied Logicon Caries Detector™ to radiographic images of both test and control surfaces and performed a second evaluation of these surfaces. Treatment was based on this second evaluation. If a surface was not treated, then this surface and the associated control surface were not included in the study.

If a test surface was treated, then its true Lesion status could be determined during cavity preparation, The dentist was asked to carefully note and record the percent penetration of the lesion into the enamel and the millimeters penetration into the dentin. The control surface exposed during the preparation of the test surface was assessed to be caries free if it exhibited no signs of cavitation or surface demineralization as indicated by a "catch" with a dental explorer. (However, without preparing this surface, one cannot exclude the possibility of subsurface demineralization.) If a control surface showed signs of cavitation and the dentist chose to restore the surface, then the dentist was asked to record the same lesion data as for the test surface. For validation purposes, intra-oral camera images of all prepared and exposed surfaces were taken and included with tabulated data.

d) Endpoint of Study:

The endpoint of the study for each individual tooth surface was either the completion of the final restoration (e.g., amalgam restoration, crown,

composite, etc.) for that surface or the decision by the dentist not to restore the tooth because of lack of caries in the dentin. The determination of caries status for each surface was made once, and it was not the intention of this study to follow a given tooth surface over time given the time and practical constraints of conducting a study in a normal private practice setting. Thus, the scope of this study was confined to a cross sectional assessment of the dentists' performance using Logicon Caries Detector at a given Point in time.

e) Sample Size

To estimate the number of dentists and surfaces required, preliminary results from seven or eight dentists were analyzed. These dentists looked at roughly 10 surfaces each with an average improvement in diagnostic accuracy of approximately 20 percent and standard deviation of approximately 35 percent. Assuming similar results from additional dentists analyzing 10 surfaces each and assuming a t-distribution for the difference between means (see Dixon and Massey, 4t4 Edition, Sec. 8-5). An estimated sample size of approximately ten dentists analyzing at least 10 surfaces each would be required to establish significance at the 5 percent level (p=0.05). Ultimately valid data on 175 surfaces from 18 dentists analyzing an average of 9.7 surfaces each were actually acquired.

4. Demographic Data

The demographic data for the clinical study are summarized in Table 2 (a. be c, d). Table 2a shows the number of study sites and the distribution of patients and tooth surfaces analyzed by state. Geographic location may have some influence on the mineral content of teeth in the local population due to variations in local diet and mineral content of the water supply. The relatively large number and range of locations of study sites throughout the Eastern and Western United States provides sufficient variability due to geographic location.

The distribution of tooth surfaces in the study by age of patients is given in Table 2b. The distribution does not appear biased with respect to the age distribution for the U.S. population. There is a weak correlation between tooth mineral content and age. Specifically, newly erupted teeth tend to have slightly lower surface enamel mineral content, with negligible difference within a year after eruption. But again, there is no evidence that the delectability of caries is age dependent. No restrictions were placed on selection of patients by age other than to restrict to selection to permanent or adult dentition.

The distribution of tooth surfaces in the study by race of patients is given in Table 2c. There is no evidence that the detectability of dental caries is race dependent.

Table 2a. Distribution of dentists and patients by geographical region in clinical study.

Region (state)	Number of Study	Number of Patient	Number of Surface From
	SITES	PATIENTS	EACH REGION
California	7	32	61
Utah	1	8	19
Idaho	1	3	5
Washington State	3	24	42
North Carolina	4	18	39
Georgia	1	2	3
New York	1	3	6
TOTAL	18	90	175

Table 2b.Distribution off patients by age In clinical study.

Age Group	Number of Patients	Number of Surfaces
10-19	12	29
19-29	20	47
30-39	23	40
40-49	18	32
50-59	6	11
60-69	5	9
70-79	3	5
>80	0	0
Unreported	2	2

Table 2c. Distribution of patients by race In clinical study.

RACE	NUMBER OF PATIENTS	NUMBER OF SURFACES
Caucasian	68	130
Black	2	4
Hispanic	3	5
Asian	2	5
Other or Unreported	15	31

Table 2d. Distribution of patients by gender In clinical study

Gender	Number if patients	Number of Surfaces
Male	41	85
Female	48	90

5. Gender Bias

The demographics relating to gender distribution are shown in Table 2d. The number of tooth surfaces from females (90) and from males %185) are consistent with an equal distribution of the sexes in the general population. Furthermore, the number of tooth surfaces from females found to have caries penetrating the dentin (53),and the number of tooth surfaces from males found to have caries penetrating the dentin (55) are consistent with an equal incidence of dental caries with respect to sex for patients selected into the study

6. Data Analysis and Results

Data were obtained from 18 dentists with 106 patients in 16 private practice offices (including 3 dentists in the Faculty Group Practice at UCLA), This included a total of 175 valid proximal tooth surfaces assessed for the presence of lesions penetrating into the dentin, A total of 218 tooth surfaces were enrolled into the study but for 27 of these surfaces, the treatment was not completed because the patient did not return for treatment or the dentist was unable to schedule the patient for the study, An additional 16 surfaces were eliminated from the study because of deviation from the study protocol resulting in the absence of usable valid data.

Effectiveness was gauged by calculating three measures of performance for dentin caries diagnosis for each dentist both before and after running Logicon Caries Detector". These were sensitivity, specificity and accuracy. Sensitivity, also referred to as the true positive identification rate or true positive, is the fraction of correct caries diagnoses made by a dentist (i.e., the number of surfaces with dentin caries correctly diagnosed divided by the total number of surfaces analyzed by the dentist which in fact have dentin caries). Specificity, also referred to as true negative, is the fraction of correct caries free diagnoses (i.e., the number of surfaces free of dentin caries correctly diagnosed divided by the total. number of surfaces analyzed by the dentist which in fact are free of dentin caries). (Note: 1-sensitivity false negative and 1-specificity = false positive.) Finally, accuracy is the fraction of all correct diagnoses made by a dentist (i.e. the number of surfaces with dentin caries correctly diagnosed plus the number of surfaces free of dentin caries correctly diagnosed divided by the total number of surfaces analyzed by the dentist).

Table 3a shows the diagnostic sensitivity of each dentist both before and after running Logicon Caries Detector was well as the difference in sensitivity. The mean sensitivity for all the dentists before running Logicon Caries Detector™ is 70.3 percent and afterwards is 90.5 percent with a difference of 20.3 percent. Considerable variation existed in the performance between dentists, but a strong trend towards improvement for most dentists was observed. To control for dentist variability, an unweighted-paired t-test was performed to determine whether the mean difference was significantly different from zero. Under the null hypothesis that the underlying true mean difference is zero, the computed two sided p value is p=0.0357. Thus, if the null hypothesis were true, we would observe a mean difference of 20.3 percent or greater less than 4 percent of the time.

Almost the same result for sensitivity was obtained using the Wilcoxon signed rank test where the null hypothesis is that the underlying true median difference is zero and p=0.0371, a significant Improvement in diagnostic sensitivity associated with the use of Logicon Caries Detector™.

Summary results for specificity is shown in Table 3b. The average (mean) specificity for all dentists before running Logicon Caries Detector™ is 88.6 percent and afterwards is 88.3 percent with a difference of -0.3 percent. Under the null hypothesis, the observed mean difference has a p value of p=0.754 (based on the paired t-test) and the observed medium difference has a p value of p=0.99 (based on the Wilcoxon test). Thus, no change in diagnostic specificity was observed.

Table 3c shows results for the diagnostic accuracy of each dentist both before and after running Logicon Caries Detector. The average (mean) accuracy for all dentists before running Logicon Caries Detector™ is 75.6 percent and afterwards is 88.3 percent with a difference of 12.8 percent. Under the null hypothesis, the observed mean difference has a p value of p=0.043 (based on the paired t-test) and the observed median difference has a p value of p=0.0537 (based on the Wilcoxon test). Thus, there is a significant improvement in diagnostic accuracy associated with the use of Logicon Caries Detector™. In view of the above, it is reasonable to conclude that the improvement in accuracy is due entirely to the improvement in sensitivity.

Three additional statistical analyses were conducted besides the two tests described above. These were: 1) a weighted paired t-tests where the weights were proportional to the number of surfaces each dentist evaluated, since all 18 dentists did not evaluate the same number of surfaces; 2) a McNemar procedure in a paired comparison with the performance on each tooth surface where the unit of analysis was tooth surface rather than the dentists' overall performance; and, 3) a logistic regression model to account for the fixed effect (in this case the treatment) of Logicon Caries Detector™ as well as the possible fixed effect of tooth type and the possible random effects of dentist or patient on diagnostic performance. The conclusions from these additional tests are the same as those in Tables I-3a, b, c, that is, there is a

significant improvement in sensitivity and accuracy but no significant difference in specificity.

Table 3a. Diagnostic sensitivity by dentist for the diagnoses of caries into the dentin on proximal surfaces before and after using Logicon Caries Detector™.

DENTIST	NUMBER OF SURFACES EXAMINED	SENSITIVITY O INITIAL EXAMS	SENSITIVETY O FINAL EXAMS	DIFFERENCE IN DENSITIVITY
AND	17	0.353	1.000	0.647
BAU	1	0.500	0.500	0.000
DON	14	0.571	1.000	0.429
GOL	2	1.000	1.000	0.000
HOR	1	0.000	1.000	1.000
HUY	9	1.000	0.889	0.111
LAB	3	1.000	0.667	0.000
LIN	1	1.000	1.000	0.000
MAG	5	0.750	1.000	1.000
MAL	2	1.000	1.000	0.000
OLS	11	1.000	1.000	0.000
ONT	6	1.000	1.000	0.000
RIC	4	0.750	1.000	0.250
SEL	6	1.000	0.833	-0.1667
STE	5	1.000	0.800	-0.200
VEN	7	0.714	0.857	0.143
VIC	0	.	.	.
WEI	13	0.615	0.846	0.321
TOTAL	108			
MEAN		0.703	0.905	0.203
St. Dev.		0.336	0.144	0.364
St. Error of Mean		0.081	0.035	0.088

Tests for Significance

*Ho: mean difference = 0, n=17: t=2.294, p = 0.0357 (< 4% chance, difference in means is significant)

**Ho. median difference = 01 n--17, signed rank = 20.5, p=0.0371 (< 4% chance, difference in medians is significant)

* Based on unweighted paired t-test: Altman, D.G., Practical Statistics for Medical Research, Chapman & Hall, 1990.

*Based on W.-1coxon Ranked-Sum Test: Kurtz, T.E., Basic Statistics, Prentice-Hall, 1.963.

Table 3b. Diagnostic specificity by dentist for the diagnoses of caries-free dentin on proximal surfaces before and after using Logicon Caries Detector™.

DENTIST	NUMBER OF SURFACES EXAMINED	SPECIFICITY OF INITIAL EXAMS	SPECIFICITY OF FINAL EXAMS	DIFFERENCE IN SPECIFICITY
AND	13	0.923	1.000	0.072
BAU	2	0.500	0.500	0.000
DON	3	1.000	1.000	0.000
GOL	1	1.000	1.000	0.000
HOR	1	1.000	1.000	0.000
HUY	4	1.000	1.000	0.000
LAB	2	1.000	1.000	0.000
LIN	1	1.000	1.000	0.000
MAG	1	1.000	1.000	0.000
MAL	0	.	.	.
OLS	8	0.250	0.125	-0.125
ONT	7	1.000	1.000	0.000
RIC	1	1.000	1.000	0.000
SEL	5	1.000	1.000	0.000
STE	2	1.000	1.000	0.000
VEN	5	1.000	1.000	0.000
VIC	2	0.500	0.500	0.000
WEI	9	0.889	0.889	0.000
Total	**67**			
MEAN		**0.886**	**0.883**	**0.003**
SD		0.232	0.256	0.037
SEM		0.056	0.062	0.009

Tests for Significance

* H_0: mean difference = 0, n=17: t=0.319, p = 0.754 (>75% chance, difference in means is not significant)

** H_0: median difference = 0, n=17, signed rank = 0.5, p=0.99 (99% chance, difference in medians is not significant)

* Based on unweighted paired t-test: Altman, D.G., *Practical Statistics for Medical Research*, Chapman & Hall, 1990.

** Based on Wilcoxon Ranked-Sum Test: Kurtz, T.E., *Basic Statistics*, Prentice-Hall, 1963.

Table 3c. Diagnostic accuracy by dentist for the diagnoses of caries or no caries into the dentin on proximal surfaces before and after using Logicon Caries Detector™.

DENTIST	NUMBER OF SURFACES EXAMINED	ACCURACY OF INITIAL EXAMS	ACCURACY OF FINAL EXAMS	DIFFERENCE IN ACCURACY
AND	30	0.600	1.000	0.400
BAU	4	0.500	0.500	0.000
DON	17	0.647	1.000	0.353
GOL	3	1.000	1.000	0.000
HOR	2	0.500	1.000	0.500
HUY	13	0.846	0.923	0.077
LAB	5	0.800	0.800	0.000
LIN	2	1.000	1.000	0.000
MAG	6	0.167	1.000	0.833
MAL	2	1.000	1.000	0.000
OLS	19	0.684	0.632	-0.053
ONT	13	1.000	1.000	0.000
RIC	5	0.800	1.000	0.200
SEL	11	1.000	0.909	-0.091
STE	7	1.000	0.857	-0.143
VEN	12	0.833	0.917	0.083
VIC	2	0.500	0.500	0.000
WEI	22	0.727	0.864	0.136
Total	**175**			
MEAN		**0.756**	**0.883**	**0.128**
std.		0.238	0.170	0.247
St. Error of the Mean		0.056	0.040	0.058

Tests for Significance

* H_0: **mean difference = 0, n=18, t=2.189, p = 0.0428 (< 5% chance, difference in means is significant)**

** H_0: **median difference = 0, n=18, signed rank = 22, p=0.0537 (< 6% chance, difference in medians is significant)**

* Based on unweighted paired t-test: Altman, D.G., *Practical Statistics for Medical Research*, Chapman & Hall, 1990.

** Based on Wilcoxon Ranked-Sum Test: Kurtz, T.E., *Basic Statistics*, Prentice-Hall, 1963.

X. CONCLUSIONS DRAWN FROM THE STUDIES

1. Risk versus Benefit Analysis

The results of the clinical study demonstrated that dentists using Logicon Caries Detector™ improved their diagnoses of lesions penetrating into the dentin without degrading their diagnoses of lesions that do not penetrate the dentin and may not require treatment

2. Safety

Logicon Caries Detector" poses no direct safety hazard to the patient because the product is data analysis software and therefore does not expose the patient to any drug or physical device. The possible indirect safety hazards would be those associated with the dentist incorrectly identifying a tooth surface as requiring restorative treatment as a result of using Logicon Caries Detector These are the usual safety hazards associated with dental. restorative treatment. The results of the clinical study show that using Logicon Caries Detector@along with conventional diagnostic methods does not result in an Increase of tooth surfaces being incorrectly @iagnosed as requiring restoration. Therefore, Logicon Caries Detector does not indirectly expose the patient to any greater safety hazard (due to unnecessary dental restorative treatment) than conventional diagnostic methods alone.

3. Effectiveness

The performance of dentists in this clinical study demonstrates that analyzing digital radiographic imagery with Logicon Caries Detector@ is effective in improving sensitivity and overall diagnostic accuracy in the detection of proximal lesions penetrating the dentin for adult dentition.

XI. PANEL RECOMENDATION

A meeting of the FDA Radiological Devices Panel took place on August 17, 1998 to review the sponsor's submission. The Panel reco=nrended approval of the application

XII. CDRH DECISION

CDRH concurred with the recomendation of the Panel. Based on the data submitted and the results, CDRH approved the PMN for the stated indications on SEP 25, 1998.

The applicants manufacturing and control facilities were inspected on September 3, 1998, and the facilities were found to be in compliance with the Good Manufacturing Practice (GMP) regulations.

X11I. APPROVAL SPECIFICATIONS

Directions for use: See the labeling.

The sale, distribution, and use of this device are restricted to prescription use in accordance with 21 CFR 801.109 within the meaning of section 520(e) of the Federal Food, Drug, and Cosmetic Act (the act) under the authority of section 515(d)(1)(B)(ii) of the act.

Warnings, Hazards to Health from Use of the Device; See Indications, Contraindications, Warnings, Precautions and Adverse Reactions in the labeling.

XIV. REFERENCES

Goaz, P,W, and White, S.C., Oral Radiology: Principals and Interpretation, C.V. Mosby, 3rd Edition, 1994.

Altman, D.G., Practical Statistics for Medical Research, Chapman & Hall, 1990.

Kurtz, T.E., Basic Statistics, Prentice Hall, 1963.

Logicon Caries Detector™

Essential Prescribing Information

Caution: Federal law restricts this device to use by or on the order of a dentist

DEVICE DESCRIPTION

Logicon Caries Detector™ is an image analysis computer software tool. It analyzes digital x-ray images acquired by a commercially available digital x-ray sensor system called RVG that is distributed by TrexTrophy Dental (formerly Trophy Radiology, Inc.) in the United States. Logicon Caries Detector™ includes 1) a CD with the executable program, tutorial presentation, demonstration images, and results of analyses of the demonstration images; and 2) a software box with User Guide, tutorial presentation, labeling, and device description, installation instructions and user authorization forms. Logicon Caries Detector™ is designed to perform its analytic calculations within less than 10 seconds on a Pentium class PC. The graphical interface displays an enlarged image of the radiograph being analyzed (with an outline of the potential lesion site shown on the image) along with two plots displaying tooth density and probability information associated with a potential lesion found by the software.

INDICATIONS FOR USE

The Logicon Caries Detector™ is a software decision aid for the diagnosis of caries that have penetrated into the dentin, on unrestored proximal surfaces of secondary dentition, through the analysis of digital intra-oral radiographic imagery. It is intended as an adjunct designed to work in conjunction with an existing TrexTrophy RVG digital x-ray radiographic system with TWI Software Version 3.0 or higher.

CONTRAINDICATIONS: None known.

WARNINGS

The detection algorithms used by Logicon Caries Detector™ are based on laboratory data for unrestored proximal surfaces of adult dentition. The results for primary dentition, occlusal surfaces or surfaces with existing restorations were not evaluated for safety and effectiveness and could be misleading.

PRECAUTIONS

- Do not analyze improperly exposed radiographs (either under-exposed or overexposed).
- Avoid analyzing overlapping proximal contacts.
- Designate the proximal surface of interest carefully to avoid extraneous radiolucencies near the occlusal surface and the cemento-enamel junction (CEJ).
- Verify that tooth edge and dentino-enamel junction (DEJ) have been found correctly.
- Rerun the program or trace the boundaries using the manual option if tooth edge or DEJ not found correctly.

ADVERSE EVENTS: Potential adverse affects are the false identification of a tooth requiring restoration and the false identification of a tooth as not requiring restoration.

CLINICAL STUDIES

The Logicon Caries Detector was tested clinically in the dental private practice setting. The objective of the study was to evaluate the effectiveness of the Logicon software as an adjunct to traditional diagnostic methods for identifying carious lesions extending into dentin on proximal surfaces of secondary dentition. The study was an unblinded open label, multi-site trial that produced clinically useful information on the use of this device in the dental office setting.

Each dentist utilized patients from a private practice setting, and was trained on identification of carious lesions to standardize their analyses. The study assessed unrestored proximal, tooth surfaces potentially requiring restorative treatment as selected by the dentist. The dentist was therefore suspicious that a lesion was present. An adjacent tooth surface that was caries free was also selected by the dentist as a control. The dentist was instructed to provide an initial diagnosis of the tooth. The dentist then selected the designated area of interest on the x-ray of the tooth with the cursor, per Logicon software instructions, and subjected the image to the Logicon analysis. The final treatment decision was made following the Logicon analysis. The treatment decision was based on the dentist's clinical judgment which included information from traditional diagnostic criteria and the additional information provided by the Logicon software. The true lesion status of a tooth, as determined during the restorative procedure, was documented using an intra-oral camera. A total of 175 proximal tooth surfaces were analyzed. 108 surfaces were diagnosed as carious and were restored. 67 surfaces were determined to be caries free and were directly observed at the time of restoration of adjacent teeth. Statistical analysis revealed that the dentists' ability to correctly diagnose proximal lesions that extended into dentin was 70.3% without use of the Logicon Caries Detector software. With the addition of the Logicon Caries Detector software, the dentists were able to improve their identification of proximal carious lesions that extended into dentin to 90.5%, true positives.

Diagnostic sensitivity in determining dentin penetration of a carious lesion was significantly improved with the use of this software. Diagnostic specificity, the ability of the dentist to determine that a surface was caries free, was unchanged (See table below).

RESULTS OF CLINICAL STUDY (reported as average +/- standard error of mean)
n = 18 dentists, 175 surfaces

MEASURE	BEFORE[1]	AFTER[2]	DIFFERENCE[3]
Sensitivity (True Positive)[4]	70.3+/-8.1%[5]	90.5+/-3.5%	+20.2+/-8.8%
Specificity (True Negative)	88.6+/-5.6%	88.3+/-6.2%	-0.3+/-0.9%

1) Diagnosis based on normal visual inspection.
2) Dentist used Logicon Caries Detector™ and re-diagnosed tooth.
3) Change in diagnoses.
4) Criteria for treatment: caries penetration into dentin.
5) Based on average performance of each dentist.

INDIVIDUALIZATION: None.

DIRECTIONS FOR USE: See User Guide.

DETAILED DEVICE DESCRIPTION: See User Guide.