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Review Article

Receiver Operating Characteristic Curve Analysis and its Application in Dentistry

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ABSTRACT:
Background: This review article tells about how to make an ROC curve by plotting the sensitivity and specificity cut off values of a diagnostic test in a graph with x- axis as specificity and y- axis as sensitivity. **Review result**: The interpretation is highest accuracy when ROC curve is to upper left border. **Conclusion**: Its application in dentistry is gaining popularity recently. E.g. Using in dental fear survey and for assessing diagnostic accuracy of different tests.
Keywords: How to make ROC curve , ROC application in dentistry, Review article.

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Introduction:
ROC create full report of sensitivity / specificity and also acts as a basic tool for diagnostic test evaluation. Nowadays, ROC curve is used to differentiate between true positive and true negatives of any predictive model.[1]
The name ROC came from signal detection theory developed during World War II for the analysis of radar images. Radar operator had to decide whether a blip on the screen represented an enemy target, a friendly ship or just noise. It measures the ability of radar receiver operators to make important distinctions. From 1970's the theory was used in medicine, radiology, biometric, forecasting of natural hazards.[1]
ROC is known as relative / receiver operating characteristic curve, as it is the comparison of two operating characteristics [TPR true positive rate & FPR false positive rate] as the criteria changes.
It is nothing but a graphical plot that illustrates the diagnostic ability of binary classification system as its discrimination threshold is varied.
The area under ROC gives an idea about the benefit of using the test in question.
It chooses the most appropriate cut off for the test, the best cut off has the highest true positive rate together with lowest false positive rate.[1]

How to make an ROC curve
One first need to be familiar with concepts of TP, TN, FP, FN. (TAB:1)
TP – patient is detected as positive by the test and clinically they are having the disease.
TN – patient is detected as negative by the test and clinically they are not having the disease.
FP - patient is detected as positive by the test but clinically they are not having the disease.
FN - patient is detected as negative by the test and clinically they are having the disease.
Sensitivity =The probability of having a positive test result among those with a positive diagnosis for the disease [true positive]

Specificity = The probability of having a negative test result among those with a negative diagnosis for the disease [false positive]

TAB: 1 Test showing positive and negative results in comparison to actual clinical situation

		Disease	
		+	-
Test	+	True positive (TP)	False positive (FP)
	-	False negative (FN)	True negative (TN)
		All with disease =TP+FN	All without disease = FP+TN

This concept of ROC is used when you compare the result of test with the clinical truth, established by the use of diagnostic procedure not involving the test in question.
The every plot in graph represents the cut off value which determines clinical sensitivity and specificity.

STEPS IN MAKING ROC curve as follows, (TAB: II,III,IV), (FIG: I,II,III,IV)

TAB II: On testing 159 healthy people and 81 sick people, diagnosis sick Y or N) are listed and ranked based on parameter concentration

ID	Parameter conc. (Higher to lower rank)	Sick
7175	33.626	Y
7167	10.630	Y
7126	9.898	N
7265	6.870	Y
7496	6.154	Y
7543	6.148	Y
7385	5.533	Y

TAB III: specificity and sensitivity is calculated and the curve is constructed by plotting the data pairs.

Parameter conc. (higher to lower rank)	Sick (Clinicaly)	Y(sum) (By Test)	N (sum) (By Test)	Sens Y by test /Total sick (81)	1-spec N by test /Total healthy(159)
33.6263	Y	1		0.0123	0.0000
10.6301	Y	2	0	0.0247	0.0000
9.8984	N	2	1	0.0247	0.0063
6.8706	Y	3	1	0.0370	0.0063
6.1545	Y	4	1	0.0494	0.0063
6.1482	Y	5	1	0.0617	0.0063
5.5334	Y	6	1	0.0741	0.0063

Sensitivity calculation for first parameter: 1/81 = 0.0123

1. Specificity calculation: 0/159 = 0.000

FIG: I First point in ROC curve

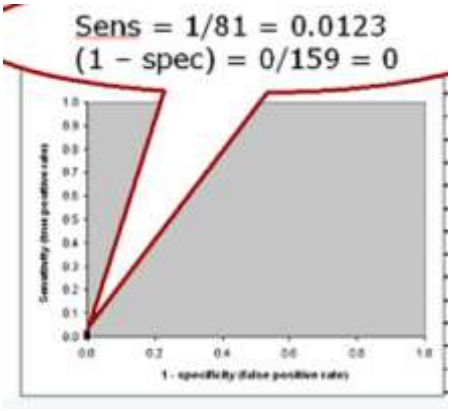


FIG: II 50 and 100th point in ROC

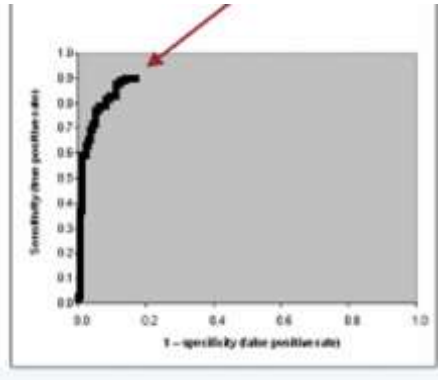


FIG: III Finalized ROC curve

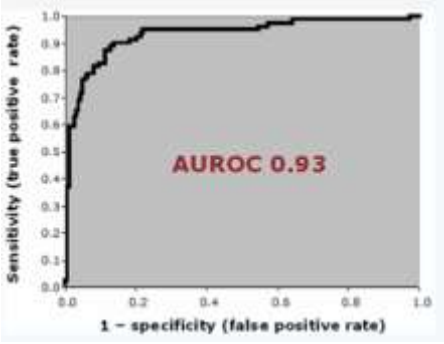
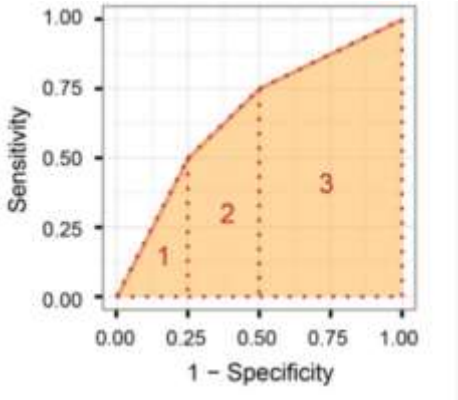


FIG IV: Way to calculate AUROC is trapezoid method. Calculates the area by joining the points at each interval values of the continuous test and draws a straight line joining the x- axis.



TAB IV: Categorization of ROC curves

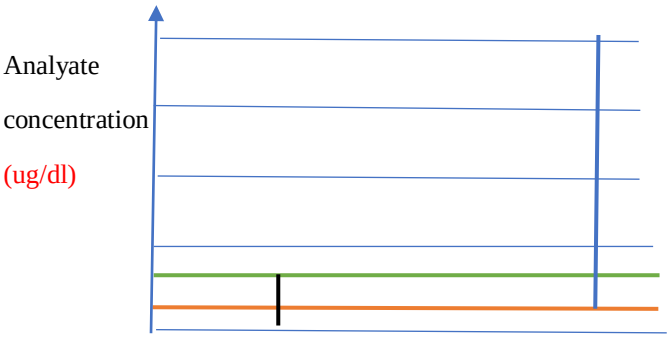
AUROC	Category
0.9 – 1.0	Very good
0.8 – 0.9	Good
0.7 – 0.8	Fair
0.6 – 0.7	Poor
0.5 – 0.6	Fail

USES OF ROC CURVE:

1. To determine cut-off value

When you change the cut-off, (FIG: V) you will get other values for true positives and negatives and false positives and negatives, while the number of patient with and without disease is same.[1]

FIG:V Graph showing analytic concentration of Healthy and Sick individual



Analytic conc of Healthy individual (Black line)

Analytic conc of Sick individual (Blue line)

1) ——— cut off value 500 ug/dl analyate concentration (92% sensitivity , 79% specificity)

2) ——— cut off value 400 ug/dl anaylate concentration (100% sensitivity,54% specificity)

(Blue line is above the orange line)

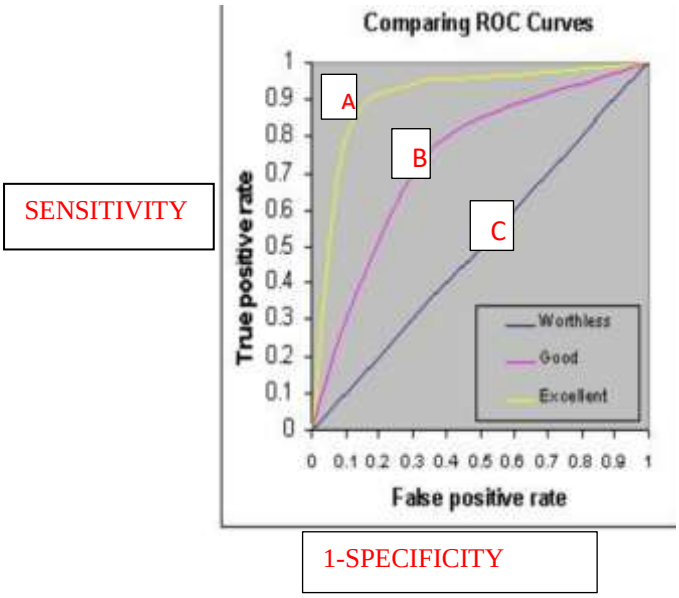
If 400 ug/dl is taken as the threshold value, the values above this considered as positive [patient is diagnosed to be diseased], the value below this considered as negative [patient diagnosed to be not having disease].
Sick indicates the true positive cases.
Healthy indicates the true negative cases.

As given in (FIG:V) cut off above 400ug/dl is diseased, so sensitivity is 100 % as all sick patient diagnosed as having disease, but the specificity is 46% because healthy individuals are also diagnosed as having disease. So, the number of individuals diagnosed as true negative is less instead of being many individuals are healthy.
So, to obtain optimum combination of sensitivity and specificity the cut off is raised to 500ug/dl. Which gives 79% specificity and 92% sensitivity.

2. To find out the accuracy of diagnostic test (FIG: VI)

ROC curve shows the relationship between clinical sensitivity and specificity for every possible cut off.
X axis shows 1- specificity
Y axis shows sensitivity
Every point in curve represent a cut off and it says the relationship of sensitivity and specificity.

FIG: VI Accuracy of different tests A,B,C



Here, Test A is superior to B because at all the cut of the TP rate is higher and FP rate is lower.

Therefore, closer the ROC curve is to the upper left border, the higher the overall accuracy of the test. (FIG: VI)

APPLICATION IN DENTISTRY: CLINICAL SIGNIFICANCE

The Previous studies which used ROC curve analysis are:

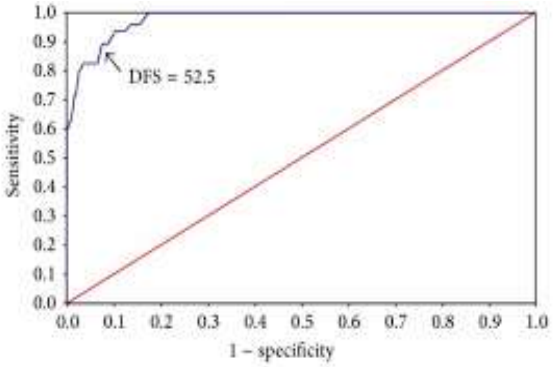
1. Ink-jet print out of radiographs on transparent film and glossy paper versus monitor display by Sebastian Kühl et al. in Clinical Oral Investigations June 2011.[2]
   They compared the sensitivity and specificity of viewing radiographs on a monitor versus to those printed out on glossy paper and transparent film. They were evaluating overall differences in gray scale contrast and they found that both monitor viewing and glossy paper print outs had higher ROC curves versus the transparent film print outs.[2]
2. Diagnostic accuracy in detecting stimulated external root resorption in cone beam computed tomography and intraoral periapical radiography by C. Durak et al. in International Endodontic Journal 2011.[3]

This study used intraoral periapical radiographs and cone beam C to evaluate simulated external root resorption of mandibular incisors. They found that the ROC curves for the CBCT were significantly higher than the intraoral periapical radiographs.[3]

DENTAL FEAR SURVEY

ROC used in the Dental fear survey (DFS) (FIG:VII). Responses to the question is assessed "Are you fearful of getting treatment from the dentist?" were given as binary responses "not fearful/low fearfulness" and "highly fearful". A DFS score of 52.5, representing the best compromise between sensitivity (0.89) and specificity (0.92), was chosen as the cut-off point for "highly fearful." Area under the curve (AUC) = 0.977.

FIG: VII



CONCLUSION

The ROC curve analysis was introduced to medical field on 1970's and ROC is used dentistry as a basic tool for diagnostic test evaluation. It uses sensitivity and specificity in a graphical plot of any predictive value. The area under roc gives idea about the benefit of using the test in question.

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