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AN AUTOMATED SYSTEM FOR IOL POWER PREDICTION

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Abstract

When planning for cataract surgery ,to achieve the desired postoperative refraction, the required power of the Intraocular lens(IOL) implant needs to be calculated. Power depends on many factors which are taken from the eye that includes refractive power, media type, actual length and model of lens used. Data Sets are collected using IOL Master 500 which is the most commonly used device in the Hospitals. It has some of the IoL power calculation equations like SRK II, SRK T, Hoffer Q and Holladay. The output power is manually calculated by the doctor. This manual selection can be made easier by an automatic prediction system. To predict this value different machine learning techniques are used. The collected data sets are trained under different machine learning models to obtain best one. From the predictions we find Regression as best model and further analysis is performed by considering RMSE values, P values etc and the power is predicted

Keywords: *Intraocular lens(IOL), automatic prediction system, RMSE values*

Introduction

Cataract surgery is the principal lens replacement refractive surgical procedure and is one of the most commonly performed surgical procedures today. The quality of the patient’s postoperative vision depends on an accurate selection of the IOL optical power, which influences the residual post-operative refraction. Improving the refractive result of cataract surgery is a challenge for IOL manufacturers, as are determining accurate methods to calculate a suitable IOL lens power. To determine the optimal IOL power, the calculation formulas are used.These formulas use data from preoperative measurements, examinations, and IOL parameters, all of which may influence the overall outcome.

The IOL power is calculated using preoperatively measured corneal power (K), axial length (AL), and an estimation of postoperative effective lens position. Errors in effective lens position estimation account for the majority of errors in IOL power calculations using the IOLMaster. In the old days the cataract was removed first and the spectacle prescription given last, the situation today is reversed.An IOL was prescribed to obtain a certain refractive effect inorder to reduce spectacle dependency.Since 1975, IOL power has been calculated using accurate eye’s corneal power and axial length (AL).Timely treatment of the cataract could endow patients with vision and help them to rehabilitate the visual function.

With the increasing development of technology and equipment,primary intraocular lens (IOL) implantation has become an acceptable treatment for cataract patients. Using these IoL power calculation formulas the doctors

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are calculating the power manually. There are some difficulties faced by doctors during this manual process which might include the possibilities of the occurrence of errors being high. So in order to overcome this an automated technique is implemented.A set of data is collected and they are trained under different machine learning techniques like Artificial Neural Networks,Decision tree, Random Forest Model and Regression. From those analyses the most accurate method is chosen.

Literature Survey

SRK II formula in the calculation of intraocular lens power

The SRK II formula is also based on the SRK I formula:
SRK I:
P = A - 0.9 K - 2.5 L (1)
where:
P : IOL power for emmetropia
K : corneal refractive power (K-reading)
L : axial length
A : A-constant
By adjusting the A-constant value to different axial length ranges, the SRK II formula is obtained:
SRK II:
P = A1 - 0.9 K - 2.5 L (2)
SRK-II had the largest mean prediction error of 1.67 D.The SRK-II formula is carried with the lowest sensitivity of prediction at±0.50,±1.00 D.The Sanders-Retzlaff-Kraff (SRK) formula has become the most widely used for implant power calculation in most part of the world. SRK II formula is introduced to reduce the prediction error of the original SRK formula in short (less than 22 mm) and long (greater than 24.5 mm axial length) eyes .SRK I used the power of the cornea,axial length and A-constant of the specific IOL, for power estimation of the IOL. This method was reasonable for all type of eyes except eyes with shorter-than-average or longer-than-average axial lengths.so in SRK-II, an alteration is made to A-constant based upon the axial length, and the results were better but still less than ideal.It is for such 'too long' and 'too short' eyeballs that SRK II formula was introduced.The SRK II formula provides a high degree of predictive accuracy at no extra cost in terms of time or money to the users.

Disadvantages:

- Can't be used for eyes with AL less than or equal to 26mm.
- Can't be used for post operated eyes.
- Short eyes prediction lacks accuracy.
- This methods has poor performance with the eyes having Higher myopia.

SRK T formula in calculation of IOL

The SRK/T formula is a theoretical approach to IOL power calculation under the SRK umbrella of formulas which is used by existing A-constants and optimization methods. Empirical optimization methods of the SRK/T model primarily consist of postoperative ACD prediction, a retina thickness correction factor and corneal refractive index.The SRK/T formula should be used for eyes greater than 26 mm.The SRK T formula used to calculate IOL power:
P = A – BL - CK
where,
P:implant power for emmetropia
L: axial length (mm)
K:average keratometry (D)
A, B, and C are constants.Values of B and C are 2.5 and 0.9, respectively, and the value of A varies with respect to the IOL design and the manufacturer. With this information, the formula can be written as follows: P = A – 2.5L - 0.9K.The SRK/T is one such formula thatrepresenting a combination of linear regression method with a theoretical eye model. Based on the nonlinear terms of the theoretical formulas, the SRK/T also incorporates empirical regression methodology for performing optimization, which result in greater accuracy.

SRK/T is best for the eyes longer than 26.00 mm.SRK/T formula can be calculated using the same A constants used with the original SRK formula.A-constant is adjustable depending on multiple variables including IOL manufacturer, style and placement within the eye.The ACD constant for SRK/T is provided by the manufacturer or calculated from the SRK-II A-constant by using the following formula: ACD = (0.62467× A) 68.747.The relationship with the A-constants is that if A decreases by 1 diopter, IOL power decreases by 1 diopter [4].There was no significant difference between the predictive abilities of SRKII or SRK/T. However, there are differences in the predictability of refractive outcomes between different IOL.

Disadvantages:

- Can’t be used for eyes with AL less than or equal to26mm.
- Can’t be used for post operated eyes.
- Short eyes prediction lacks accuracy.
- This methods has poor performance with the eyes havingHigher myopia.

The Hoffer Q formula in the calculation of intraocular lens power

The Hoffer Q, was developed to predict the anterior chamber depth (ACD) for theoretic intraocular lens (IOL) power formulas. It relies on a personalized ACD, axial length, and corneal curvature.Hoffer formula use the postoperative AC depth A change in the true post-operative AC depth will affect the refractive status of the eye. A change in 1 mm causes a 1.5D change in the final refraction. Hence, these constants must be personalized to accommodate any consistent shift that might affect IOL power calculation.

Hoffer Q formula can be,P = [1336/A – C – 0.05] - 1.336/[(1.336) – (C +0.05)] K + R 1000
where,

P = IOL power
A = Axial length
C = estimated post-op ACD
K = corneal power (in Diopters)
R = corneal radius (in mm)

The modified Hoffer Q formula has an advantage over the other formulas because it calculates a stronger power IOL for emmetropia than the other formulas in presence of a very
flat cornea and it does not require a correction in its ELP calculations.

Disadvantages:

- Good with eyes having AL less than 22mm.
- Better with short eyes.
- Not good for eyes with higher myopia.

1.1. Holladay 2 intraocular lens power formula

The Holladay 2 formula is conceptually based on the Holladay 1 formula; however it uses seven parameters for predicting the surgeon factor. These are the AL, corneal power, ACD, lens thickness, age, white-to-white corneal diameter and preoperative refraction data.

Holladay 2 formula can be written as,

D = a0+(a1*ACD)+(a2*AL)

Carl Zeiss Meditec Inc. has made it a priority to increase access to this formula by integrating it directly into the IOLMaster itself.The IOLMaster 500 is the only instrument on the market that has the Holladay 2 formula inside the unit.Holladay 2 formula determines Effective Lens Position (ELP) is calculated using 7 parameters :Axial length,K-reading,White-to-white,Pre-op rx,Anterior chamber depth,Lens thickness,Patient’s age.This formula has been found to be highly accurate for a large variety of patient eyes.The Holladay 2 formula performed well with and without lens thickness value.It can be used in eyes with axial length (short, normal, long) and their anterior segment size (small, normal, large).

Disadvantages:

- Requires input measurements of 7 variables.
- Can’t be used for post operated eyes.
- It's not good for minus power iol implants.
- Lack prediction in extremely long eyes.
- Not better with concave lenses.
- Good with eyes having AL in the range of 22mm to 26mm.

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IMPLEMENTATION

Step 1 — Gathering and Exploring the data:
Dataset is collected from around 1000 patients in Little Flower hospital, Angamaly,Ernakulam.Dataset consist of personal details of patient like name, age, id etc and eye parameters taken using IOL master 5 device which includes Axial length,/keratometry,Lens name etc.

Step 2 — Data Preparation:
The dataset is for our regression model by splitting our data into two distinct sets of data in which 80% for Training and 20% for Testing.

Step 3 — Splitting the Data
Preparing the data for our regression model by splitting our data into two distinct sets of data in which 80% for Training and 20% for Testing.

Step 4 — Initializing the Model and Parameters
Many parameters are used in power prediction out of which,the mandatory ones are Axial lenth, Keratometry 1 and keratometry 2, Lens constant, SRK II value.Right machine learning model is selected which suits the problem by comparing 4 different models.

Decision Trees:

Decision tree builds classification in the form of a tree structure.A decision node has two or more branches and a leaf node represents a classification or decision. The topmost decision node in a tree which corresponds to the best predictor called root node. Decision trees can handle both categorical and numerical data.

Random Forest model:

Random forest is a supervised learning algorithm which is used for both classification as well as regression. But however, it is mainly used for classification problems.It is an ensemble method which is better than a single decision tree because it reduces the over-fitting by averaging the result.

Artificial Neural Network:

A neural network consists of units (neurons), arranged in layers, which convert an input vector into some output.The networks are defined to be feedforward. Weightings are applied to the signals passing from one unit to another, and it is these weightings which are tuned in the training phase to adapt a neural network to the particular problem at hand[2].

Regression Analysis:

Regression is a supervised machine learning technique.This method helps to predict a numerical value based on set of prior data. There are two regression techniques Simple linear regression and Multiple linear regression. Simple linear regression is the basic and commonly used type for predictive analysis.It is a statistical approach for modelling relationship between a dependent variable and a given set of independent variables.

Multiple linear regression describes how a single response variable depends linearly on a number of predictor variables.And for this reason we have used multiple linear regression in our project.Instead of using 1 variable to predict the outcome of another variable, MLR uses 2 or more variables to do so. The output of a regression model is a mathematical function similar to the line below with y, representing the dependent variable which we want to predict and 1 n; representing the coefficients (values attach the independent variable)and x1xn; representing the independent variables: y = 0 + 1:x1 + : : : + n:xn [3].

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MODELS	ACCURACY
Artificial Neural Network	94 %
Decision Tree	79.2 %
Random Forest Model	91.8 %
Regression Analysis	93.4 %

By comparing all these models,accuracy values obtained under each evaluation is shown in the above table.It is clear that the accuracy value for ANN is the best. But we are having linear dependent data sets and we need to estimate a single parameter we are considering regression technique.

Step 5 — Training and Cross-Validation
Dataset is splitted into training and testing data. 80% data is used for training.It is again splitted to target and features in which target is dependent variable and features are independent variable.Features are trained into a model to get targets as output.Hence a regression model is obtained.

Step 6 — Testing
Now the test data is passed through the trained regression model to get the predicted result.

Step 7 — Evaluation
It's finally to evaluate our regression model.We have divided dataset into different clusters of each cluster contains approximately 100 data sets. We perform multiple linear regression in these individual clusters and the root mean square error (rmse), R squared, Probability (P- value) values are calculated. It is shown in the table below. From the table it is clear that the cluster 1(0-100) is having the least rmse value for the training data. So it is chosen for the further analysis.

DATA SETS	R SQUARED	RMSE (Training data)	RMSE(Testing data)	Avg P-VALUE
1-100	0.967	**0.288**	0.407	0.475
101-200	0.925	0.445	0.541	0.132
201-300	0.875	0.672	0.579	**0.082**
301-400	0.967	0.472	0.464	0.603
401-500	**0.973**	0.336	0.647	0.268
501-600	0.932	0.444	0.485	0.423
601-700	0.865	0.584	**0.265**	0.352
701-800	0.900	0.861	0.588	0.31
801-900	0.556	1.21	0.612	0.276
901-1000	0.934	0.351	0.603	0.320

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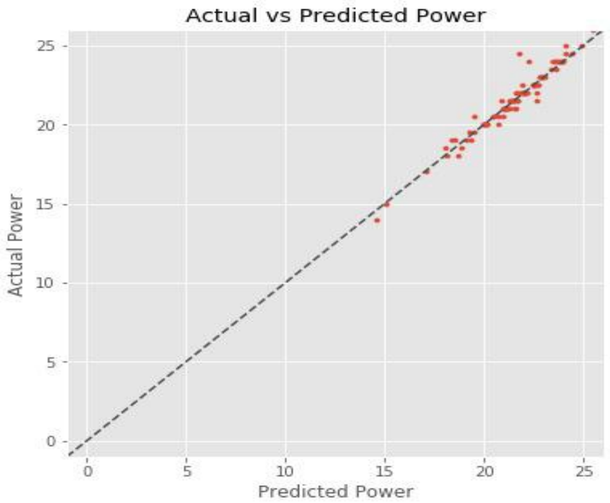
Conclusions

The software for IoL power prediction was successfully implemented. The values taken from the 1000 patients are used as input and the output is predicted. The input data is applied to different machine learning techniques out of which the Regression model is selected. This method uses variable input values to predict the output. The dataset is also clustered to get the best cluster which is then used for training. The best accurate result is obtained under this technique. Hoffer Q is superior for Short Eyes, and the SRK/T shows a trend toward being better in very long eyes. All performed equally well in the eyes with an average axial length.This study, adding the Holladay 2, showed that the Holladay 2 equals the Hoffer Q in short eyes, the Holladay 1 and Hoffer Q are equivalent in average eyes, and the SRK/T and Holladay 2 perform equally in medium long eyes, but the SRK/T produces a trend toward better results in very long eyes.

Result

The graph (Fig 1) below shows the output obtained after the analysis of the complete data set.



The X Axis of the graph represents the predicted power and the Y axis represents actual power. The pointed dots depicts the input values. Since the dots are closer to the central line of the graph,It makes clear that the results are accurate.

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