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DETERMINATION OF POSITION OF INTRAOCULAR LENS IMPLANT BY DEEP LEARNING ALGORITHMS IN PATIENTS OF CATARACT SURGERY

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Abstract: *The current study was designed to predict the position of the intraocular lens in patients who have undergone cataract surgery using machine learning. A retrospective study was conducted in the Department of Ophthalmology at Lahore General Hospital from May 2022- May 2023. 150 patients undergoing cataract surgery by implanting intraocular lenses were selected for the study. The axial length, central corneal thickness, corneal curvature radius, and horizontal corneal diameter were noted during the surgery. The data set of 300 eyes was analyzed using the following techniques; regression model, regression trees, Support Vector Machine, and Gaussian Process Regression Models. The GPR technique with the exponential kernel gives perfect prediction compared to other algorithms. A mean root square of 0.185 mm was noted for postoperative AQD and 0.179 mm for the prediction of postoperative LEQ. The horizontal corneal diameter did not vary significantly in both models, and central corneal thickness was not associated with estimating postoperative AQD. Gaussian process regression is the best machine learning algorithm to predict the intraocular lens position in cataract surgery patients.*

Keywords: Machine Learning, Intraocular Lens, Cataract Surgery, Artificial Intelligence

Introduction

Artificial technology has recently been incorporated in every field of life, from engineering to medical sciences (Malik et al., 2019). Machine learning, a major field of artificial intelligence, is used to assess relationships with the help of measured data. For instance, weather predictions are made using historical data and developing predictive models.
Fyodorov (Sramka et al., 2019) and Gernet (Xin et al., 2020) first devised a formula for calculating the refractive power of intraocular lenses, and since then, all the calculations have been done by this formula. The eye model of this formula consists of an intraocular lens, target refraction, and cornea, which are reduced by a thin lens. After the lens calculation and biometrics, the intraocular lens position is still unknown, so an estimate must be made preoperatively (Balyen and Peto, 2019). Calculation formulas have different values of the cornea's refractive power with respect to the keratometric index and have different approaches to estimating ELP. Hence, though the optical model makes optical formulas, it contains an important experiential component, i.e., the estimation of ELP. Modification of lens calculation formula require lens constants which in turn influence ELP. Therefore, refractive power of the lens can be modified in the algorithm, but ELP remains a fictive parameter (Ting et al., 2019).
This study aims to predict the position of the intraocular lens in patients who have undergone cataract surgery using machine learning.

Methodology

A retrospective study was conducted in the Department of Ophthalmology at Lahore General Hospital from May 2022- May 2023. 150 patients undergoing cataract surgery by implanting intraocular lenses were selected for the study. All the patients provided informed consent to participate in the study. The ethical board of the hospital approved the study design.
The axial length, central corneal thickness, corneal curvature radius, and horizontal corneal diameter were noted during the surgery. Anterior chamber depth, central lens thickness, and intraocular lens were measured by HR-optical coherence tomography before and 2-4 months after surgery. R1 and R2 calculated the mean radius.
The data set of 300 eyes was analyzed by MATLAB version 2019. The set was divided into five equal-sized groups, and each group was used as validation data set one by one, and the algorithm was adjusted

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with respect to the other four groups. The data set was analyzed using the following techniques; regression model, regression trees, Support Vector Machine, and Gaussian Process Regression Models.

Results

Table I describes the values of target sizes and effect sizes. Table II explains the prediction of the target sizes, i.e., postoperative AQD and LEQ, after applying machine learning techniques. The GPR technique with the exponential kernel gives perfect prediction compared to other algorithms as the findings are obtained by the 5-fold method, so the predictions are credible. A mean root square of 0.185 mm was noted for postoperative AQD and 0.179 mm for the prediction of postoperative LEQ. Table III shows that horizontal corneal diameter did not vary significantly in both models, and central corneal thickness was not associated with estimating postoperative AQD.

Table I: Preoperative and postoperative findings

Variables	Mean ± SD	Median	Minimum	Maximum
Axial length	23 ± 1.3	22.9	18.88	30.5
Central corneal thickness	551 ± 31	551	452	655
Preoperative anterior chamber depth	2.6 ± 0.3	2.7	1.65	3.8
A central thickness of the natural lens	4.4 ± 0.3	3.5	3.3	5.6
Horizontal corneal diameter	10.8 ± 0.3	11	10.5	12
R mean	6.6 ± 0.2	7.1	6.8	8.2
Distance from the equator of the intraocular lens to the anterior corneal vertex	4.6 ± 0.3	4.5	3.7	5.8
Postoperative anterior chamber depth	3.5 ± 0.3	3.6	2.6	4.9

Table II: Findings of Machine Learning Techniques

Technique	Option	Prediction of postoperative AQD				Prediction of postoperative LEQ			
		RMSE	R^2	MSE	MAE	RMSE	R^2	MSE	MAE
Regression	Linear	0.179	0.725	0.031	0.139	0.185	0.697	0.032	0.140
	Interactions linear regression	0.188	0.715	0.030	0.135	0.197	0.668	0.037	0.148
	Robust linear regression	0.185	0.725	0.031	0.139	0.185	0.697	0.032	0.138
	Stepwise linear regression	0.190	0.715	0.033	0.134	0.190	0.688	0.035	0.142
Regression tree	Fine regression tree	0.239	0.545	0.055	0.188	0.235	0.518	0.055	0.178
	Medium regression tree	0.238	0.555	0.054	0.189	0.245	0.477	0.058	0.187
	Coarse regression tree	0.249	0.505	0.060	0.198	0.247	0.468	0.032	0.200
Support vector machine	Linear kernel SVM	0.187	0.725	0.035	0.138	0.186	0.697	0.035	0.136
	Quadratic kernel SVM	0.189	0.715	0.035	0.141	0.195	0.678	0.038	0.145
	Cubic kernel SVM	0.193	0.705	0.037	0.147	0.197	0.658	0.039	0.145

	Gaussian kernel SVM	0.191	0.705	0.036	0.145	0.188	0.697	0.030	0.140
Gaussian process regression	Squared exponential GPR	0.186	0.735	0.033	0.138	0.185	0.697	0.032	0.140
	Exponential GPR	0.185	0.735	0.034	0.136	0.179	0.618	0.030	0.132
	Rational quadratic GPR	0.186	0.735	0.033	0.141	0.185	0.697	0.032	0.140

Table III: Multi-regression analysis

	Coefficient	SE	P	Coefficient	SE	P
	Prediction of postoperative AQD			**Prediction of postoperative LEQ**		
Constant	0.481	0.087	0.319	0.855	0.485	0.079
Axial length	0.051	0.009	<0.001	0.035	0.009	<0.001
Central corneal thickness	0.128 x10^{-3}	0.345 x10^{-3}	0.705	1.140x 10^{-3}	0.340 x10^{-3}	0.001
Preoperative anterior chamber depth	0.052	0.049	<0.001	0.740	0.049	<0.001
A central thickness of the natural lens	0.374	0.036	<0.001	0.375	0.035	<0.001
Horizontal corneal diameter	0.033	0.039	0.431	0.035	0.038	0.385
R mean	-0.238	0.059	<0.001	-0.185	0.059	0.001

Discussion

We conducted this study to predict the position of the intraocular lens in cataract surgery cases using machine learning techniques. Our findings indicate that Gaussian process regression performs best with RMSE of 0.185 mm and R^2 of 0.735 mm.
In Gonzalez et al., the regression model was also the algorithm that showed the best results for predicting intraocular lenses. It had an RMSE of 0.380 mm and R^2 of 0.995 mm, which complies with the findings of our study (Carmona González and Palomino Bautista, 2021).
Results in Fan et al. back the results of our study. The study reported that the Gaussian process machine was the best-suited technique. It had an R^2 of 0.73 mm and an RMSE of 0.68 mm. These values are higher due to the large sample size in this study (Fan et al., 2022).
Langenbucher et al. reported similar results to our study. Gaussian prediction regression with an RMSE of 0.280 mm and an SD of the prediction error of 0.273 mm showed the best results when tested to predict the position of the intraocular lens (Langenbucher et al., 2022).
In another recent study by Langenbucher et al. Gaussian process regression was the best technique by 5- fold method. It had an R^2 value of 0.755 mm and an RMSE of 0.195 mm. Our results do not vary significantly from this study due to the comparable sample size (Langenbucher et al., 2020).
Our study has some limitations. Our study was single-centered and only included patients undergoing cataract surgery. Multicenter studies with distinct sample inclusion may yield more useful information.

Conclusion

Gaussian process regression is the best machine learning algorithm to predict intraocular lens position in patients undergoing cataract surgery.

Conflict of interest

The authors declared absence of conflict of interest.

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