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Data Preprocessing for Quality Analysis of Contact Lens Material in Ophthalmology using Factor Analysis

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Abstract— **This paper focuses on Factor analysis performed on contact lens material. The Factor Analysis on the contact lens material and interpretation are the central steps in this research process. The extracted contact lens data are comprehended and interpreted to trigger the research. Analysis based on a wide range of variables can be tedious and time consuming. The contact lens materials such as RGP, Soft and Hybrid are considered as the source of dataset for factor analysis. Principle Component Analysis is the method adopted to do Factor Analysis. From the result it is found, out of 10 parameters 5 parameters are considered to be the key parameters for identifying the quality contact lens material in the field of ophthalmology.**

Keywords— Contact Lens, RGP Lens, Soft Lens , Hybrid Lens, Factor Analysis, PCA, Ophathalmology.

I. INTRODUCTION

Factor analysis is commonly known as a common factor model or theoretical model. Factor analysis is a statistical procedure to study the interrelationship among the variables in an effort to find a new set of factors, fewer in number, than the original variables so that the factors are common among the original variables. It explains the dimensions or factors for complex events. It is a mathematical procedure to simplify the interrelated measure to discover the pattern in the set of variables [1] .

Factor analysis allows testing theories involving variables which are hard to measure directly. On the prosaic level of analysis, factor analysis helps to establish the observed variables if the measuring facts underlying the same factors with varying reliability. Computing methods of factor analysis are stated below:

$OB_1 = k_{11} F_1 + k_{12} F_2 + k_{13} F_3 + \ldots\ldots + k_{1m} F_m + k_1 U_1$

$OB_2 = k_{21} F_1 + k_{22} F_2 + k_{23} F_3 + \ldots\ldots\ldots + k_{2m} F_m + k_2 U_2$

…..

….

$OB_n = k_{n1} F_1 + k_{n2} F_2 + k_{n3} F_3 + \ldots\ldots + k_{nm} F_m + k_n U_m$

where

$OB_1, OB_2 \ldots\ldots OB_n$ are observed variables

$F_1, F_2 \ldots\ldots F_m$ are common factors

$U_1, U_2 \ldots U_n$ are unique factors expressed in linear function

k_{11} , k_{21} ….. k_{nm} are the observed variables from the factors. The coefficients of these factors are the weights in the same way as regression coefficient.

Factor analysis basically follows four steps. They are:

i. Computing the correlation of all variables
ii. Determining the required factors or factor extraction
iii. Rotating factors or interpreting the factors
iv. Calculating the score of each factor.

Factor analysis has its applications in varied fields like medicine, economics, marketing, geography and in various other technological advancements of computers. Factor analysis is required to check the absence of univariate and multivariate outliers [2]. More likelihood of the samples can be identified using factor analysis [3].

II. RELATED WORK

In the field of Astrophysics an algorithm proposed for strong, galaxy scale gravitational lenses in the residual image using basic vectors obtained from principal component analysis. PCA (Principal Component Analysis) based galaxy subtraction acts better than the traditional subtraction model for fitting data in astrophysics[4].The exploration of consumption pattern in food and nutrients was analysed using factor analysis methods among the rural adult population in India[5] .

The research work focused on the PCA process for extraction of factors. Principle Component Analyses are extraction of components selected at maximum variation in the original data set. By the implementation of factor analysis the parameters opted to identify the quality contact lens material of a larger number is reduced to fewer dimensions with the available data. PCA has vital application in the field of material science, were PCA was used to study of SWNTs (Single-walled Carbon Nano Tubes) on coarse grained simulations and atomistic fine grained simulation. In PCA was implemented to identify the dynamic factors[6]. The prevalence patient to reach vision centers in rural area was found using factor analysis. According to the result the patient found it very difficult to travel to Vision care centers[7]. PCA was a classical statistical method for image processing applications and this method further dimensionally reduces the feature vectors[8].

In the field of epidemiology the development of an instrument for Eye Care Expectation Survey (ECES) was found by the cross section study using factor analysis[9]. In the area of investigation, ophthalmology and visual science PCA was used as a diagnostic tool for checking the loss of terpenoids in meibum and the plethora of positive biological functions. In this the lower level of cholesterol esters are determined between the lipid layer deposits of the eye with the patient age[10]. The psychology field also implemented factor analysis and exploratory factor analysis to check the happy medium accuracy and completeness with over helming technical complexity[11] .

PCA was also implemented in the field of climatology to check the performance of meteorological variability of the surface precipitation and temperature by using daily cumulative rain showered in the winter season in the region of Sardinia[12].

Ioannis Tranoudis, and Nathan Efron [13] determined that the water content and diameter is reduced significantly when the temperature is raised to 20-35^0 C. The lens quality remained unchanged with the lens made of HEMA/MAA (HEMA: 2-hydoxyl-ethyl methacrylate, MAA: methacrylic acid) at 70%. High water content material does not dehydrate easily because of its low relative change in oxygen transmissibility for a period of 6 hours. Oxygen permeability (OP) is a parameter of contact lens, which permits the oxygen reach the eye by diffusion, while Dk/t is a parameter which denotes the transmissibility level. The Dk/t and Dk values significantly depend on the measurement of the physiological values given for the evaluation of contact lens performance. The high transmission capabilities of varied Dk/t values have low impact on the physiological performance of the lenses. It is also understood that the Dk value above 70 are better. Using the stack method the characterization and the accurate measurement of oxygen transmissibility and permeability are measured. It resulted that the significance level of physiological data remains significant by using BOAT (Biological Oxygen Apparent Transmissibility) and EOP (Equivalent Oxygen Percentage) methods.[14]. Factor analysis shows the relationship and pattern which can be easily interpreted among the variables[15].

Factor analysis was done on the parameters of contact lens types such as RGP (Rigid Gas Permeable), Soft and Hybrid which are identified using ID3 algorithm. Principal component regression analysis was performed in identifying the water content of contact lenses. The sample taken for the analysis was implemented with PerkinElmer Spectrum Quant and PCA tool to produce the calibration of the contact lenses[16] .

III. PROPOSED WORK

I) Factor Analysis For Quality Analysis Of Contact Lens (QACL) Material In Ophthalmology

The contact lens in which the collected data set consists of 9 parameters is processed further to identify the factors essential to construct an algorithm need for quality enhancement of contact lens material. This essential parameter provides a way for the designing and development of quality lens material for primary refractive errors.

II) Parameters Adopted

There are three types of contact lenses, namely RGP lenses, Soft lenses and Hybrid lenses. These lenses are used to reduce the power for the patients who are affected from the preliminary eye problems. In the concept of quality inspection of the lens material, contact lenses can be grouped according to the following key factors:

- Lens Material
- Lens Design
- Period of comfort while wearing lenses
- Parameters required designing a lens
- Side effects due to lens wear

The questionnaires are obtained from the contact lens article [17] which promoted to carry away the research. The above mentioned processes are basically performed manually. The shape, the size of the contact lens is designed using lathe-cut and molding. The quality of the contact lens analysed using machines. The side effects when wearing the contact lenses are not analyzed initially, instead they checked the lens for correction of vision; fitment of the contact lens to the cornea and reduction of power after wearing the contact lens are analyzed. Therefore it was necessary to apply a condition to minimize the side effects and provide a stable vision to the eyes. The research is to analyze and study the parameters that are required to design a quality lens. The parameters are classified as:

i. Lens dimensions
   - Diameter
   - Base curve radius
   - Thickness
   - Power

ii. Optical properties
   - Water content
   - Dk value
   - Refractive index
   - Specific gravity
   - Light Transmittance

A brief examination of the types of materials and the plethora of lens designs will demonstrate that care needs to be taken when selecting lens material – whether for ‘off-the-peg’ lenses or custom-designed. The four main differences to bear in mind are[18]:

i. *Oxygen permeability:* the higher the OP, the lower the refractive index of the material and, as with spectacle lenses, the thicker the final lens

ii. *Polymeric mix:* silicone, fluorine, polymethylmethacrylate or other “backbone” components, cross-linking agents

iii. *Refractive index:* The refracting power of a lens is directly related to its refractive index and determines the thickness and curvature of the optical device.

iv. *Wettability:Wettability* refers to adherence of two materials. It refers to the adhesive and cohesive force balance between lens surfaces.

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The FDA gives each contact lens material a generic name. In general, all hydrogel and silicone hydrogel lens generic names end in the suffix “filcon” and all nonhydrogel lenses ends in “focon”[19].

III) Preprocessing

Preprocessing steps involve identifying the observed variable (parameters) represents the original variables which are used to identify how much the observed variable correlates and interpreted with the original variables. These observed variables are grouped into factors which underlying input variables that are named as independent groups which are dependent with each other.

Table – 1.1 : Contact Lens Manufacturers and Brands

Manufacturers	Brands
Bausch and Lomb	Soft lens Toric and Pure Vision
Johnson and Johnson	Acuvue Oasys , Acuvue 2
CIBA Vision	O_2 optix, Air optix and Focus Dailies
Cooper Vision	Proclear, Proclear EP and Proclear Multifocal

From table 1.1, the dataset of the contact lens material are taken from various brands of Bausch and Lomb, Air optrix, Johnson and Johnson and Cooper vision. The optical and physical properties of the contact lenses are the observed variables used in this analysis. The analysis study motivates to identify a unified model which mainly corresponds to reduce the side effects of wearing contact lens of refractive error patients.

Tables 1.2,1.3 and 1.4 illustrate the dataset required for factor analysis of contact types such as RGP lens, soft lens and hybrid lens respectively.

Table – 1.2 : RGP Contact Lens materials

RGP Lens Materials
Boston II Itafocon A
Boston IV Itafocon B
Boston Equalens Itaflourofocon A
Flosi Kolfocon A
Fluorex 700 Flusilfocon A
Fluofocon 60 paflufocon B
Fluoroperm 30 paflufocon C
Fluoroperm 92 paflufocon A
Fluoroperm 151 paflufocon D
Menicon Z
ONSI 56 Onsifocon A
OP-2 Lotifocon B
OP-3 Lotifocon A
OP-6 Lotifocon C
Optacryl60
Paraperm EW Pasifocon C
Paraperm O2 Pasifocon A
Tyro 97 Hofocon A

Table – 1.3 : Soft Contact Lens material

Soft Lens Material
Hioxifilcon B
Lotrafilcon A
Lotrafilcon B
Galyfilcon A
Narafilcon A
Senofilcon A
ComfilconA
Enfilcon A
Alphafilcon A
Hioxifilcon A
Hioxifilcon D
Nelfilcon A
Balafilcon A
Etafilcon A
Ocufilcon C
Ocufilcon D
Phemfilcon A
Methfilcon A
Methafilcon A
Methafilcon B
Vilfilcon A
Hilafilcon B
Polymacon

Table – 1.4 : Hybrid Contact Lens materials

Hybrid Lens Name
Paflufocon D hem-iberfilcon A
Petrafocon A hem-iberfilcon A

The contact lens materials like RGP, Soft and Hybrid considered as the source and the parameters such as Water content, Dk value, Diameter, Base Curve Radius, Thickness, Power, Refractive Index, Specific gravity and Light transmittance are collected. Using these parameters factorization was performed. Table 1.5 shows the parameters list.

Table – 1.5 : Parameters obtained for factor analysis

Parameters
Water Content
Dk
Diameter
Base Curve Radius
Thickness
Power
Refractive Index
Specific Gravity
Light Transmittance

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The Factor analyses are performed among the data referred in table 1.2, 1.3 and 1.4. These data on the mentioned table have different range of values in diameter, base curve radius and thickness. From the values in diameter, base curve radius and thickness is expanded for each data set and taken for processing. The sample data set taken for analysis is about 46,313. Table 1.6 illustrates the samples used for analysis.

Table 1.6 Sample dataset

Lens Name	RGP Lens Material- Boston II Itafocon A	Soft Lens Material Lotrafilcon A	Hybrid Lens Material Paflufocon D hem-iberfilcon A
Water Content	20	24	27
Dk	12	140	100
Diameter	7.0 to 11.5	13.8	14.5
Base curve radius	5.0 to 9.00	8.6	7.1 to 8.54
Thickness	0.07 to 0.65	0.08	0.12 to 0.3
Power	-3.00	-3.00	-3.00
Refractive Index	1.47	1.43	1.53
Specific Gravity	1.13	1.08	1.1
Light Transmittance	91	96	91

The parameters such as water content, Dk, Diameter, base curve radius, thickness, refractive index, power, specific gravity and light transmittance are shown with their recorded values of each contact lens brand. Using this dataset of 46,313 samples factor analysis was performed. Power is considered as constant with 3.00D during manufacturing and it's a dependent parameter, hence not used in factor analysis. SPSS tool was used to perform factor analysis. The evaluation reports of factor analysis are followed as per the steps given below.

Level 1: Construction of Data involves formation of parameters with its corresponding inputs are collected as shown in table 1.6.

Level 2: This level of process performs descriptive statistics with 46,313 data. In this the mean and standard deviation are found. Table 1.7 shows the descriptive statistics of the given data.

Table – 1.7 : Descriptive Statistics

	Mean	Std. Deviation	Analysis N
Water Content	23.67	8.294	46313
Dk	52.63	42.973	46313
Diameter	8.636	2.1481	46313
Base curve Radius	7.329	1.0330	46313
Thickness	.9103	2.17947	46313
Refractive Index	1.4568	.01843	46313
Specific Gravity	1.134	.0388	46313
Light Transmittance	93.15	4.792	46313

Level 3: This level of factor analysis performs Correlation for the data. Correlation was performed with the eight parameters which represents the relationship between the factors and variables. From table 1.8 it is clear that the design element of the matrix will have the value of 1.

Table -1.8 : Correlation Matrix

	WC	Dk	D	BCR	T	RI	SG	LT
WC	1.000	.112	.470	.055	-.020	-.598	-.179	-.289
Dk	.112	1.000	-.100	.120	.065	-.164	.234	.314
D	.470	-.100	1.000	.226	-.014	-.096	-.243	-.323
BCR	.055	.120	.226	1.000	-.142	-.046	.008	.230
T	-.020	.065	-.014	-.142	1.000	.006	-.181	-.319
RI	-.598	-.164	-.096	-.046	.006	1.000	-.184	.194
SG	-.179	.234	-.243	.008	-.181	-.184	1.000	.095
LT	-.289	.314	-.323	.230	-.319	.194	.095	1.000

Level 4: After finding the correlation among the matrix data, the component matrix is identified. The data used here are subjected to perform factor analysis in two stages. Though the stages are two both the outputs can be requested at the same time. To perform the analysis, SPSS tool was used. In stage 1, SPSS was used to extract factors with an Eigen value of one or higher. The method used here is principal component method (PCA).

Table – 1.9 Extraction of Components

	Components			
	1	2	3	4
Water Content	.827	.352	-.015	-.012
Diameter	.694	.004	.469	.030
Light Transmittance	-.655	.433	.303	.167
Refractive Index	-.563	-.547	.386	.155
Dk	-.138	.643	-.249	.563
Specific Gravity	-.320	.486	-.441	-.357
Base curve Radius	.027	.450	.627	.239
Thickness	.209	-.410	-.428	.683

After implementing Principal component matrix, table 1.9 shows the extraction of the components. The result shows that 4 components have been extracted with given data. PCA extracted maximum variance from the data set with each component, thus reduces the large number of variables into a smaller number of variables.

Level 5: This level is an important process of the factor analysis which known as interpretation. In this level the first step is to interpret the output from the factors extracted, with their Eigen value and the cumulative percentage of the variance. The Cumulative percentage statistics are as shown in table 1.10.

Table – 1.10: Total Variance Obtained using PCA

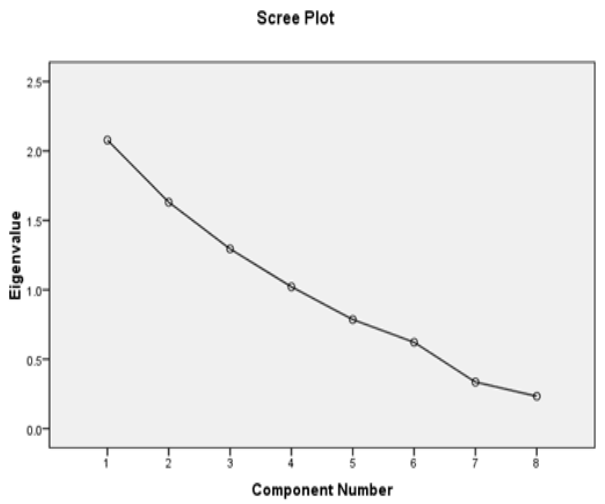
Component	Initial Eigen values			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.078	25.978	25.978	2.078	25.978	25.978	1.865	23.307	23.307
2	1.631	20.383	46.361	1.631	20.383	46.361	1.513	18.916	42.223
3	1.294	16.180	62.541	1.294	16.180	62.541	1.439	17.986	60.209
4	1.021	12.768	75.309	1.021	12.768	75.309	1.208	15.100	75.309
5	.786	9.821	85.130						
6	.622	7.770	92.900						
7	.335	4.190	97.090						
8	.233	2.910	100.000						

At this level of the process using PCA the initial solution of each variable is standardized to have a mean of 0.0 and a standard deviation of $\pm$ 1.0. Thus, the variance of each variable is 1.0. The total variance obtained is 8. Since the single variable can account for 1.0 unit of variance, or should have the Eigen value greater than1.0.

Further, the four factors have been extracted using the Eigen value. The Eigen value considered based on the criteria that the Eigen value should be 1 or higher. According to the cumulative percentage of variance, the four factors have been extracted with a cumulative percentage of 75.3% of the total variance (information contained in the original variables).

This is an ideal method to reduce the number of variables from 8 to 4 underlying factors. While the loss is only about 24.7% of the information content 75.3% is retained by the 4 factors extracted out of the 8 original variables. This represents a reasonable good solution for the above mentioned problem. Now, interpreting the 4 extracted factors are justified with rotated and unrotated matrices as shown in figure 1.1

Level 6: After finding the factors the next level is to plot the graph using Cattell's screen plot using the Eigen value associated with each of the extracted factors against each of the other factors. Figure 1.1 shows the extracted factors.



Level 7: At this level, called rotation of factors, where the rows correspond to the original variables and the columns to the factors are compared and the required factors are obtained as shown in table 1.11.

Table – 1.11: Rotated Component Matrix using PCA

	Component			
	1	2	3	4
Refractive Index	-.866	.193	-.033	.018
Water Content	.840	.320	-.007	.010
Specific Gravity	.185	-.735	.120	-.267
Diameter	.401	.725	-.068	-.108
Dk	.240	-.282	.766	.295
Light Transmittance	-.391	-.187	.676	-.303
Base curve Radius	.045	.430	.609	-.310
Thickness	-.013	.088	-.058	.922

From Table 1.11, the rotated factor matrix, it is noticed that variable numbered 1 and 2 have the loading -.866 and .840 on factor 1 which has the highest loading nearest to 1.000. This suggests that factor 1 is the combination of two original variables.

Table 1.12 suggests a similar grouping. Therefore, there is no problem in interpreting factor 1 of column 1, as a combination of refractive index and water content which are the properties of contact lens material named as "optical 1". Interpretation for factor 2 was done and the result obtained from the table 1.11 is -.735 and .725 of column 2 with high loadings. The values obtained as factor 2 are specific gravity and diameter which are named "opticalphysical1". Factor 3 was obtained from table 1.12 has the values as .766, .676 and .609 from column 3 of the rotated matrix which are Dk values, light transmittance and base curve radius respectively. This group is named as "opticalphysical2" based on their internal properties. Factor 4 obtained had the value 0.922 of column 4 which determine the thickness of the contact lens. This factor 4 was named as "optical2".

Level 8: This level is mainly implemented to find the communality of the variables taken from the data set. The data set of the lens material was taken for communality, which finds proportion of the variance by summing of its squared factor loading. The component matrix indicates the correlation of each variable with each factor. The communality table is shown in Table 1.13

The communalities of the 8 variables are given in table 1.13. As is evident from the table, the proportion of variance in each variable accounted for by the four factors which are not same.

Using Factor analysis in analysis of QCLA material gave 75% of the result about the factor required for designing quality lens analysis algorithms. The key parameters required for designing the QLAA were obtained.

Table – 1.13: Communalities obtained using PCA

	Initial	Extraction
Water Content	1.000	.808
Dk	1.000	.811
Diameter	1.000	.703
Base curve Radius	1.000	.654
Thickness	1.000	.861
Refractive Index	1.000	.789
Specific Gravity	1.000	.661
Light Transmittance	1.000	.737

Extraction Method: Principal Component Analysis.

IV. RESULTS

Identification of Key Parameters

Factor 1 consists of two variables, namely refractive error and water content. Both the variables are having high loadings; factor 1 denotes the measured optical values and these variables are independent variables required for QLAA. Factor 2 is the measure of optical and physical properties of the contact lenses. The variables have high loadings according to the communalities of specific gravity and diameter. The values are .661 and .703 respectively.

For the quality analysis, diameter had high variance accounted by the 4 Factors. Specific Gravity is dependent variable of water content which possesses optical properties where density of water is high. Specific Gravity is also high and vice versa. Therefore Specific Gravity can be discarded for further process in quality analysis. Diameter which is the physical properties of the lens is the key parameters for QLAA.

Factor 3 is the combination of three variables namely Dk, Light Transmittance and Base curve radius, it possess both the physical and optical properties of the contact lenses. Dk, Light Transmittance and Base Curve Radius had high factor loadings where their communalities are .811, .737 and .654. In this, Dk is the optical property of the contact lenses which is an independent variable where communality was high when compared to Light Transmittance and BCR. This paves the way that the Dk variable considered as a key parameter of Quality analysis.

The Variables Light Transmittance, Base curve Radius are dependent variable. Light Transmittance is the optical property which is dependent on the refractive index of the material that is, the amount of light that enters into the lens material is specified. When Refractive index is high, then Light Transmittance will also be high and vice versa. Light Transmittance was considered to be low factor, which will not reflect much for the next level of process hence it was not considered for QLAA.

Base curve radius (BCR) is a dependent variable of the diameter which possesses physical property of the contact lenses that specifies the shape of the lens material which fit to the cornea. Based on the diameter of the lens BCR is calculated for the lenses, BCR and diameter are dependent variables. If the diameter is known the radius of the lens can be noted efficiently. So it is possible to eliminate the factor BCR. Therefore BCR was eliminated from QLAA.

Factor 4 contains one variable which is the thickness of the material that possesses physical properties of the lens. The factor loadings and the communality are high which is taken as the key parameters for QLAA.

From the factor analysis, dependent variables such as Specific Gravity, Light Transmittance, BCR are eliminated from the process of quality analysis. The reason is that the above variables are constructed based on the key parameters such as Water Content, Dk, Diameter, Refractive Index and Thickness. If the value of the key parameters either increase or decrease, the value of the dependent variables also increase or decrease to make the quality analysis process very efficient.

The key parameters identified using factor analysis are the building blocks for designing the quality lens material which helps in reducing side effects when using the contact lenses for the patients. It also helps to improve comfort and visualize objects clearly when wearing the contact lenses.

V. CONCLUSION

In this process, the necessary factors were found among the group of parameters used in manufacturing of contact lenses. By using this analysis the next phase of framing a prototype for Quality analysis of contact lens material is generated. From the eight parameters such as water content, Dk, diameter, base curve radius, thickness, and refractive index, specific gravity and light transmittance five parameters are obtained for performing QLAA of contact lens material. The five parameters identified are Water Content, Dk, Diameter, Refractive Index and Thickness.

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