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FEA of contact between scleral buckle and human eye tissues

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Abstract

Human eye is one of the physiologically complex organs of human body. With aging or may be because of family history, eye problems are prevalent. One such problem is Retinal Detachment. It is the disorder of eye in which retina separates from layer underneath. To solve this problem, Scleral Buckling surgery is the recommended solution. The surgery is established by depressing the eye with band or buckle parallel to the area of retinal breaks. As a result, spherical shape of human eye changes to egg like structure. Changes in shape of eye may pose treatment challenges in repair of eye tissues. This research work aims to verify physical effectiveness and surgical after effects of scleral buckle surgery. In this research, response of a human eye deployed with scleral buckle is investigated by Finite Element Method (FEM). The study throws light upon problems raised after ring is indented on the eye. Human Eye model has been created by referring dimensions from literature & solution is obtained by applying suitable boundary conditions and loads. The highest displacement of 3.3596 mm for pressure value 0.7 MPa is found in Vitreous Humor. A maximum stress of 4050.3 KPa for 0.7 MPa pressure value is found at contact surface of sclera where ring touches Scleral outer surface. The maximum displacement of 3.3481 mm & a stress of 35.9 KPa at 0.7 MPa pressure is observed on retina typically in the regions of likely detachment. This indicates scleral buckle could facilitate restoration of detachment.

Keywords: Intra-ocular pressure (IOP), Finite element method (FEM)

1. Introduction

Human Eye is one of the most delicate parts of human body. So, problems related to eye are also a challenge to ophthalmologists. In this, Medical Sciences is constantly providing a helping hand to ophthalmologist to successfully solve the problems. In this effort, Engineers contribute to know the after effects of the surgeries in which implants are also used as per the requirement [1]. But still research in some areas is not observed up to the mark by the doctors. So, one such problem is fixing the Retinal Detachment. It is a disorder of the eye in which the retina separates from the layer underneath. To cure this, Scleral Buckling Surgery is done [2].

Retinal detachment (RD) is treated by ophthalmology surgery called as scleral buckling. The surgery is carried out by depressing the eye with the help of a band or a buckle parallel to the area of retinal breaks. Many post-procedure clinical evaluations were carried out to calculate the deformation of the eye leading to observatory changes with different results and conclusions. As per different surgical specifications, for example, extension and location of the buckle, buckle thickness, the amount of indentation etc. scleral buckling method can be varied. Some of the preoperative conditions of the eye involves eyes subjected to corneal thinning, which is an important issue which is to be considered in the procedure. Finally, a study involving eye conditions and types of surgical variables is required for analyzing their effects on vision and eye deformation. Derived information will help in predicting results of surgery. Ciliary-body edema, angle-closed glaucoma are the changes in the eye vision which are caused by scleral buckling surgery [3].

FEA is the most common practice used in Engineering. It is employed for calculating the stresses and deformation in eye simulation structures against applied loads. This simulation is done by creating finite element model of eye. Thus the effect of contact buckling on the eye is simulated. FEA helps to simulate the real life situations by assigning suitable boundary conditions [2]. Thus, the realistic effects could be analyzed [1-3].

Considering the simplified eye model and treating eye to be axisymmetric one-fourth human eye is modelled and a contact area where ring fits on outer layer of the eye is provided in geometric model so as to reduce the computational time and apply load on specific area [1].

Nonlinear hyper-elastic material models for human eye tissues pose several convergence related difficulties and obtaining solution becomes more difficult when there are as high as seven tissue material components in human eye model. Therefore, considering solution difficulties this study excludes complex five parameter Mooney-Rivlin material models. However, some studies involving a few the tissue components have considered hyperplastic material of a few of the tissues [1,2,4].

There are various biological problems arising in human eye which are successfully dealt by ophthalmologists and eye surgeons, however use of implants, prosthesis and external supporting structures during treatments/surgery may pose complications.

Onchocerciasis (river blindness), Childhood blindness, Diabetic retinopathy, Refractive errors, Cataract and low vision, Age-related macular degeneration, corneal opacities, Glaucoma, Genetic eye diseases etc. are some of the eye related problems faced worldwide. Among these Refractive errors, Cataract, Glaucoma, Retinal detachments, Diabetic retinopathy are dominating eye related problems.

a) Treatment for these problems varies from disease to disease. Treatment for some of the diseases is as follows-Refractive error. It can include correction with prescription glasses, contact lenses or with refractive surgery, such as LASIK or PRK.
b) Cataract - The symptoms of early cataract is improved with new eyeglasses, brighter lighting, anti-glare sunglasses, or magnifying lenses. If these measures do not help, surgery is the only effective treatment. Surgery involves removing the cloudy lens and replacing it with an artificial lens.
c) Glaucoma - The most common laser treatments for glaucoma are selective laser trabeculoplasty (SLT) and argon laser trabeculoplasty (ALT).

Retina, being one of the most important parts of human eye, utmost care is taken to prevent any damage to it. It is the sensory membrane that lines the inner surface of the back of the eyeball. It's composed of several layers, including one that contains specialized cells called photo receptors. So the various problems related to retina are Floaters, Retinal Detachment, Macular Degeneration, Retinitis Pigmentosa, and Diabetic Eye Disease. Among these, Retinal Detachment is a disorder of the eye in which the retina separates from the layer underneath. It can be caused because of –

a) Family history of retinal detachment
b) Extreme nearsightedness (myopia)
c) Aging Effect

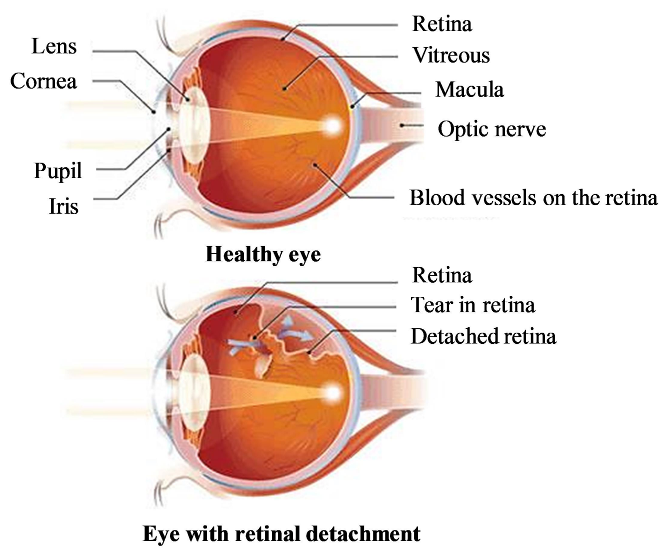

Figure 1 Healthy eye and eye with retinal detachment [5].

Three types of eye surgery can be done for Retinal Detachment: vitrectomy, scleral buckling, and pneumatic retinopexy. From the discussion with ophthalmologists, Scleral Buckling Surgery is most commonly used to fix retinal detachment. It is a surgical procedure used to repair a retinal detachment. In this, the Scleral Buckle is the outer supporting layer of the eyeball and it is a RING type mechanical structure. The diameter of the ring is less than the diameter of the eye. So, the ring is stretched and put on the diametrical part of the eye. This tightly placed ring on the eye presses the eye ball which in turn increases the IOP inside the eye and pushes the retina back to its place. Figure 2 shows the human eye with retinal detachment and eye after scleral buckling surgery.

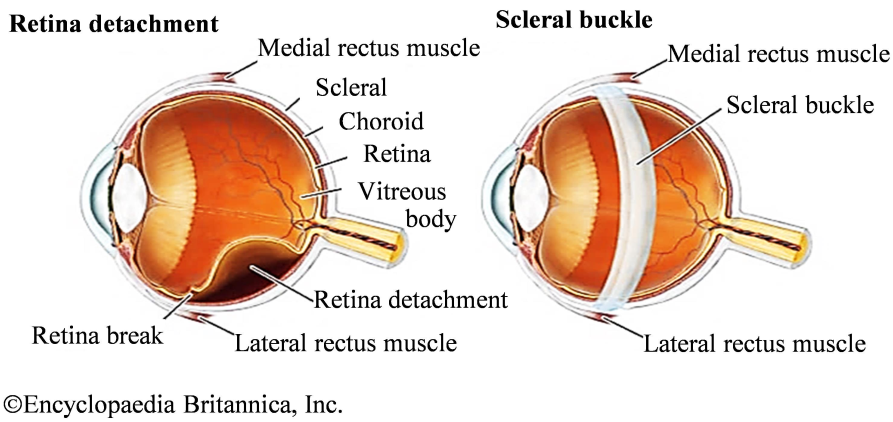

Figure 2 Buckling surgery for retinal detachment [6].

From the discussion with doctors, it is clear that many of the diseases which occur in the eye can be cured pharmaceutically or by using drugs, but when implants or prosthesis are used, the design and understanding of these mechanical structures require engineering knowledge. Thus, mechanical engineers can contribute in understanding physics of pre and post-operative procedures.

From the literature survey, it was found that after effects of this surgery are not clear. This research work would emphasis on researching about the stresses & deformations human eye has to undergo once buckle (ring) is fitted on the eye. So that incase of any complications, prior measures can be taken in the surgery.

2. Materials and methods

2.1 Methodology

As reported by many researchers [1-4], FEA is found that the most feasible, fairly accurate and time saving method to investigate the biomechanical interactions of prostheses and human eye tissue.

In this, biomechanical analysis of human eye, a scleral buckling surgery is simulated by Finite Element Analysis. Research has already been done to study the material properties of the human eye. Thus, material properties of various components of eye [1] have been taken from previous research papers.

The model can be obtained by the two different methods -

1) MRI file of a human eye can be obtained from the Radiologist. MRI file or DICOM file with .dcm extension using the MIMICS software can be converted into STL file. Then by using the 3Matic software STL file is converted into IGES file with extension .igs

2) Human Eye can be modeled in modeling software by obtaining the dimensions of eye from existing literature.

The model should have volumes, then element type and material properties can be assigned to the model. After this, meshed model can be obtained. Thereafter to simulate the real situation, loads are applied and solution is generated. Subsequently the FE model is validated by comparing the results and findings with earlier researchers.

The method of converting MRI file to ANSYS compatible file turned out to be time consuming and cumbersome. Thus, an eye model is created in ANSYS v 14 software using the dimensions and material properties from the literature [1,3]. Considering the simplified eye model and treating eye to be axisymmetric one-fourth human eye is modelled and a contact area where ring fits on outer layer of the eye is provided in geometric model so as to reduce the computational time and apply load on specific area.

Figure 3 shows exploded view of the eye model and shapes of tissue components are illustrated around the periphery for clarity in understanding.

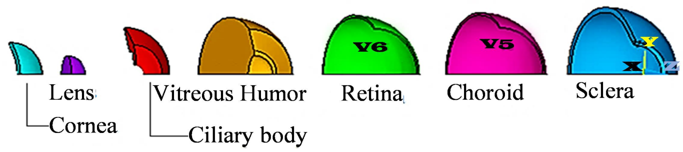

Figure 3 Exploded view of eye model with ring.

Figure 4 is an assembly of the various tissues placed intact depicting physiological arrangement in human eye.

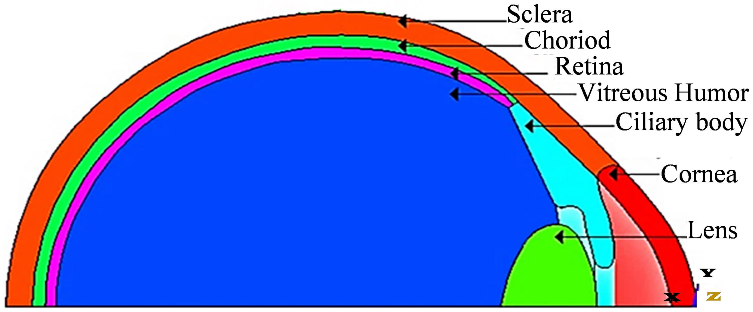

Figure 4 Combined eye model with different components of eye.

Material attributes are set for corresponding tissue components which ensures right value of material properties to the corresponding tissue components. Choice of appropriate elements is to be made while discretization or meshing all the tissue components of human eye. Boundary conditions like constraints, load, pressure, etc. are then imposed on the meshed model.

2.2 Material properties

Linear material models representing elastic materials for human eye tissues are considered. Young's Modulus, Poisson's Ratio and Density for different eye components are isotropic and given in Table 1.

Table 1 Material properties of human eye [1].

Components of human eye	Young's Modulus (MPa)	Poisson's Ratio	Density (kg/mm3)
Cornea	6.1	0.494	1.4e-6
Lens	1.5	0.49	3.15e-7
Ciliary Body	11	0.4	1.6e-6
Sclera	48	0.454	1.4e-6
Choroid	0.03	0.49	9.99e-7
Retina	0.03	0.49	1.033e-6
Vitreous humor	0.042	0.49	9.99e-7

2.3 Selection of modal parameters

The following geometric dimensions of model are chosen as listed in Table 2 and the dimensions are shown in Figure 5. These dimensions of ring are provided by Ophthalmologists.

Table 2 Modal parameters of ring.

Modal parameters	Ring
Inner diameter (mm)	11.82
Outer diameter (mm)	13.82
Width (mm)	2

Source - Ophthalmologists.

For avoiding complexities in analysis, ring is not modelled. To have the effect of ring, the contact area between Sclera and ring is modelled on the outer surface of the Sclera (outermost layer of human eye) on which the boundary conditions are applied.

For better understanding of the assembly of the human eye model with ring, Figure 5 shows the longitudinal and axial dimensions of eye and the ring.

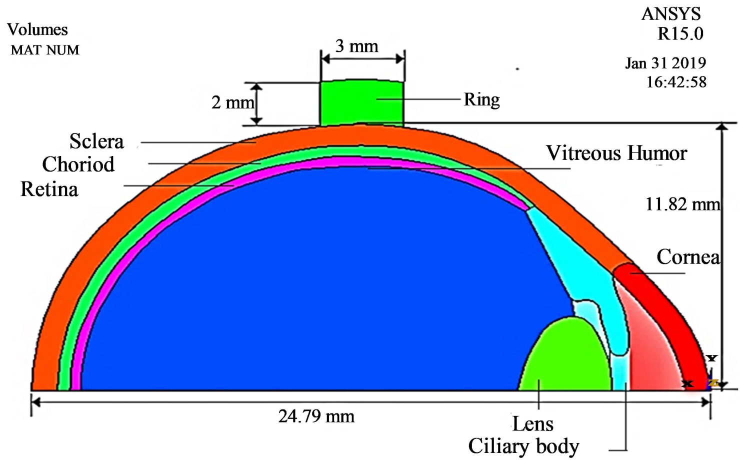

Figure 5 Axial and longitudinal dimensions of eye model and ring.

Figure 6 shows the contact area between ring and scleral tissue of human eye.

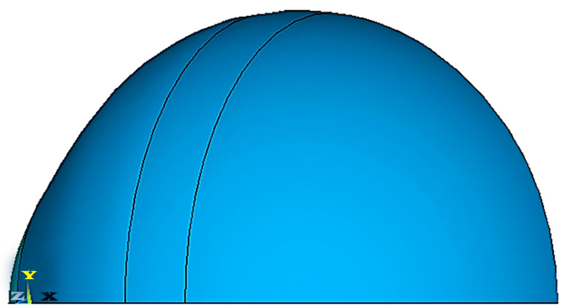

Figure 6 Isometric view of eye model showing the contact area between sclera and ring.

Differences between dimensions of the modelled eye and dimensions of eye from the literature [3] are given in Table 3.

Table 3 Differences between dimensions of the modelled eye and dimensions of eye from the literature.

Parameters	Dimensions of model from literature	Dimensions of model, created in ANSYS v 14
Axial length	25.24 mm	24.79 mm
Longitudinal length	12.44 mm	11.82m

It is challenge to create the model with accurate dimensions as mentioned in the literature. The dimensions of human eye differ from person to person. So, from discussion with doctors, +/- 1mm difference in the dimensions of eye model are permissible. Therefore, these dimensions were finalized for this research work.

2.4 Defining element types

Element type Brick 8 Node 185 is used for the purpose of volume mesh for eye. It has 8 nodes having three degrees of freedom at each node: translations in the nodal x, y, and z direction. The element has hyper elasticity, large deflection, large strain capabilities and many more.

2.5 Preparation and generation of mesh in eye model

Eye model generation is the first step of modeling. Because of its complex shape it is tough to model an eye. So, rough design of an eye model was imported from GrabCAD then, using GrabCAD model and dimensions of an eye model from literature, model is designed. Model being symmetric, only ¼ of the eye is constructed using revolving option available with ANSYS 15.0. Firstly, the 2D model is modelled by plotting keypoints using rough geometry of eye model.

Figure 7 shows meshed one-fourth volume of human eye with various human eye components and their respective volume numbers.

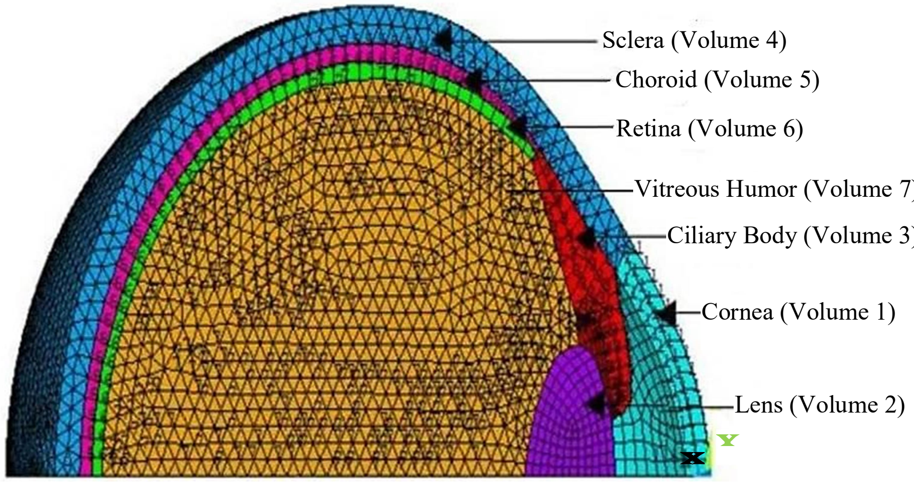

Figure 7 3D meshed geometry.

Volumes are meshed using sweep option. Volume number 4 (Sclera) & 7 (Vitreous Humor) did not get swept due irregular geometry. Therefore, tetrahedral mesh was used for these volumes.

Meshing or discretization creates elements and nodes. This process is important because now the geometry will be divided into elements so that while analyzing, the results can be obtained on these elements and nodes.

The procedure for meshing is as follows:

a) The mesh is generated using the mesh tool.
b) Elemental edge length is set to be 0.5 mm.

The accuracy of the solution depends upon the quality of mesh. Finer the mesh, more accurate results are obtained. It is because finer mesh implies that the more number of nodes and elements are generated, and hence the effect of loadings can be determined and analyzed for each node and element. Thus, by varying the edge length accuracy can be obtained. Lesser the edge length more will be number of elements and nodes, hence desirable, however solving is time consuming process for the solver to converge the solution.

Mesh sensitivity analysis is carried out to check any variations in primary variables like displacements and secondary variables like stress and strains. It is observed that there are no significant variations in the resulting parameters for a particular setting that produce the number of nodes and elements as shown in Table4. Table 4 below lists element and node count for different components of human eye. Even after fine meshing i.e. increasing the number of nodes and elements, no variation in results are observed, and hence it is acceptable. Vitreous Humor has the largest number of element and node count i.e. 13878 and 9426 respectively, whereas Lens has lowest number of element and node count i.e. 451 and 674 respectively.

Table 4 Element and node count for different components of human eye.

Volume Number	Components of human eye	Element count	Node count
1.	Cornea	612	777
2.	Lens	451	674
3.	Ciliary body	629	1008
4.	Sclera	1080	4324
5.	Choriod	847	1878
6.	Retina	867	1838
7.	Vitreous humor	13878	9426

2.6 Application of symmetry boundary conditions on symmetric areas along XY and XZ planes

Symmetry boundary conditions are applied on symmetric areas along XY and XZ planes so that the results generated on ¼ of the eye model could resemble results of fully revolved eye model (Figure 8)

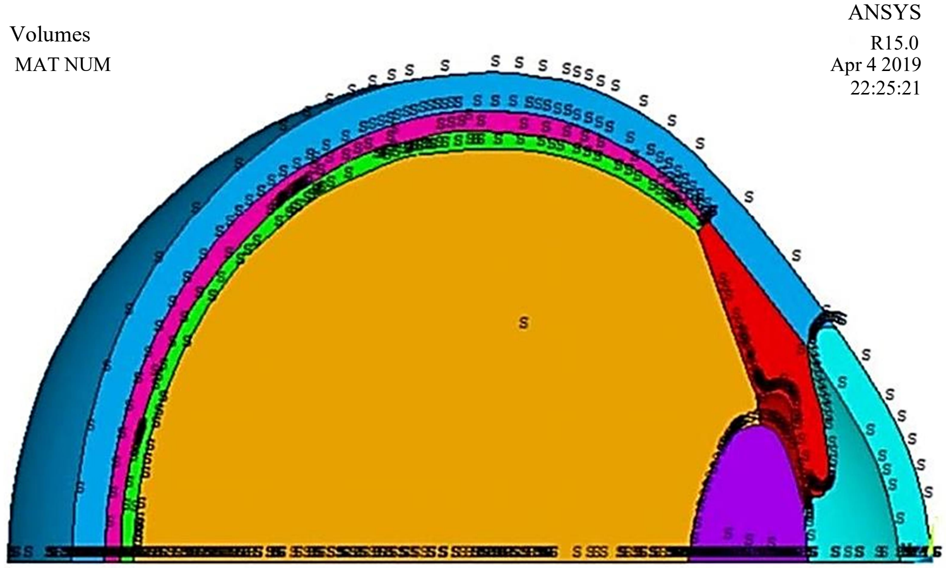

Figure 8 Symmetry boundary conditions are applied to side areas.

2.7 Defining boundary conditions for the model

Nodes along the axis are set to be zero in y & z direction because in actual situation eye is held by the muscles, which do not allow the eye to move in y & z direction [4]. For simplicity purpose, muscles holding eye at its place are not modelled, but their effect is given on the model in the form of boundary condition. The boundary condition when applied to the geometry is displayed with symbol as shown in Figure 9.

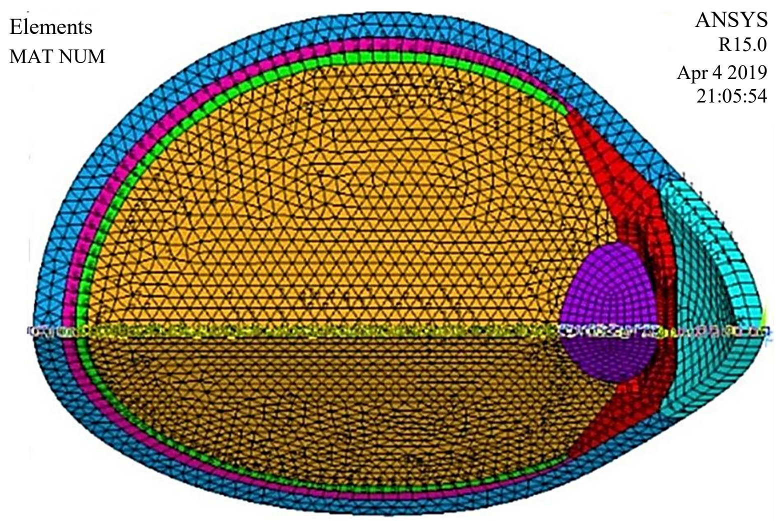

Figure 9 Displacement at axial nodes in Y & Z direction is set zero.

The next condition requires that the ring be fitted on the outer surface of the eye model with an interference fit. There are two ways to do that either one can establish nonlinear contact pairs or determine the pressure at which the scleral buckle would acquire size/dimensions of outer surface of any eye. To avoid complexity the later is approach is adopted. Nonlinear contact analysis is not carried out in this study and hence no contact pairs or friction is required. To simulate that the pressure is applied on the cross-sectional area of ring modelled on outer layer of the eye. As the outer diameter of eye is 12.44 mm and inner diameter of ring is 11.82 mm, as given in Table 3 and Table 4 i.e. inner diameter of ring is less than the diameter of the eye. Therefore, to fit the ring on the eye, it has to be stretched i.e. its inner diameter is made larger than diameter of the eye and then is wrapped around the eye surface. Hence, at equilibrium condition, the diameter of the eye will be same as that of inner diameter of the ring. So by using FEA, the values of pressure exerted by the ring on the eye are interpreted at which the diameter of the eye is equal to the inner diameter of the ring. The pressure values found out are 0.2 MPa, 0.4 MPa, 0.5MPa, 0.6 MPa and 0.7 MPa. These pressure values are applied on the outer surface of the ring and thus simulating the actual situation. The boundary condition when applied to the geometry is displayed with symbol as shown in Figure 10.

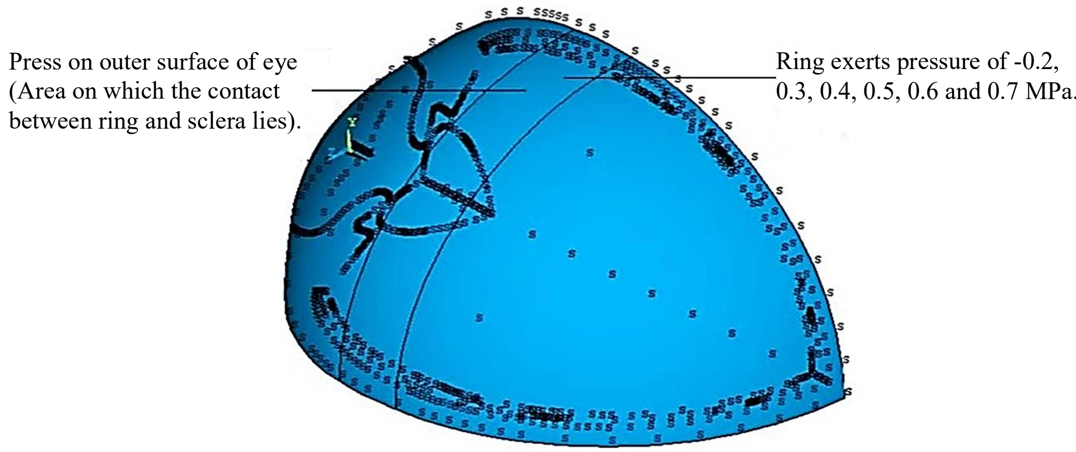

Figure 10 Contact area between ring and scleral tissue.

With this, the modeling/pre-processing of eye geometry is completed. Loads are applied in pre-processing step and then for solution processing is done with the help of CPU.
In alignment with the boundary conditions being discussed above, it is also important to known which solver is to be used to find the solution of the problem by FEA. In the solution of the analysis, the computer takes over and solves the simultaneous equations that the finite element method generates. The results of the solution are:

a) Nodal degree of freedom values, which form the primary solution
b) Derived values, which form the element solution

The element solution is usually calculated at the elements integration points. The ANSYS program writes the results to the database as well as to the results file (Jobname.RST).

Several methods of solving the simultaneous equations are available in the ANSYS program: frontal solution, sparse solution, Jacobi Conjugate Gradient (JCG) solution, Incomplete Cholesky Gradient (ICCG) solution, Preconditioned Conjugate Gradient (PCG) solution, and an automatic iterative solver option (ITER).

Sparse Direct Solver (Direct Elimination Solver) selected as a solver for the given problem statement for it provides a solution to robust problems and when solution speed are required (nonlinear analysis); for linear analysis where iterative solvers are slow to converge.

The sparse direct solver is based on a direct elimination of equations as opposed to iterative solvers, where the solution is obtained through indirect means, that is, through the iterative solution. Also the sparse direct solver does not pose poorly conditioned matrices and hence there is no any difficulty in producing a solution. Therefore, sparse solver is used in the analysis.

3. Results and discussion

After building the model and obtaining the solution, some critical questions are to be answered. Post-processors in the ANSYS program help to answer the questions. Post-processing involves reviewing the results of analysis. It is probably the most important step in the analysis because it tries to explain how the applied loads affect the design, how good the finite element mesh is and so on.

Two post processors are available to review the results: the general post-processor and the time-history postprocessor. General post-processor allows reviewing the results over the entire model at specific load steps and substeps (or at specific time-points or frequencies). In a static structural analysis, for example, stress distribution at a particular step can be displayed.

This research work aims to determine the structural parameters like stress, strain and displacements. The stresses and strains considered are the von Mises stresses and von Mises strains. It is proposed that yield occurs when the distortion component exceeds that at the yield point for a simple tensile test and von Mises theory is more popular due to its approach of treating failure criteria from the energy perspective. Most of the ductile material failures can be predicted using von Mises criteria. This is the reason why von Mises stress and strain are studied.

The following nodal plots of structural parameters like von Mises Stress, von Mises strain and Displacement are obtained when pressure of 0.7 MPa is imparted on the geometry. The nodal plots of only one pressure condition are plotted whereas the values at other pressures have been summarized further after individual results of various human eye components are discussed.

3.1 Results at 0.2 MPa applied on the outer surface of the eye by the ring

As discussed in 2.6 pressures of 0.2 MPa, 0.4 MPa, 0.5 MPa, 0.6 MPa and 0.7 MPa is applied. The Figure 11 to Figure 14 shows von Mises stresses and displacement in the human eye at 0.2 MPa and displacement and stress values at other pressure values are listed in Table 5 and Table 6 at the end of this chapter. Displacement values are maximum at posterior ends (the end of an eye opposite to its front portion i.e. cornea), while stress values are maximum near distal ends. High stress values are found in the region where ring applies the pressure on the eye. Human eye with a ring during buckling surgery resembles the case of a balloon filled with water being pressed by a rubber band at the middle. Since, in balloon the longitudinal ends are free to expand as a response of the pressure applied by the band, same is the case with human eye. Therefore, maximum deformation takes place at the posterior end of the eye. The objective of study in research work is to find critical regions in the eye during buckling surgery for that evaluation of the structural parameters i.e. stress and displacement is necessary. The effect on eye ball at elevated pressures during buckling surgery is of prime interest in this research.

Figure 11 indicates the displacement caused in the eye after 0.2 MPa pressure is applied on outer surface of the ring. Figure 11 (A) is the isometric view and (B) shows the back view of the eye model. Maximum displacement is obtained in the posterior region of the eye.

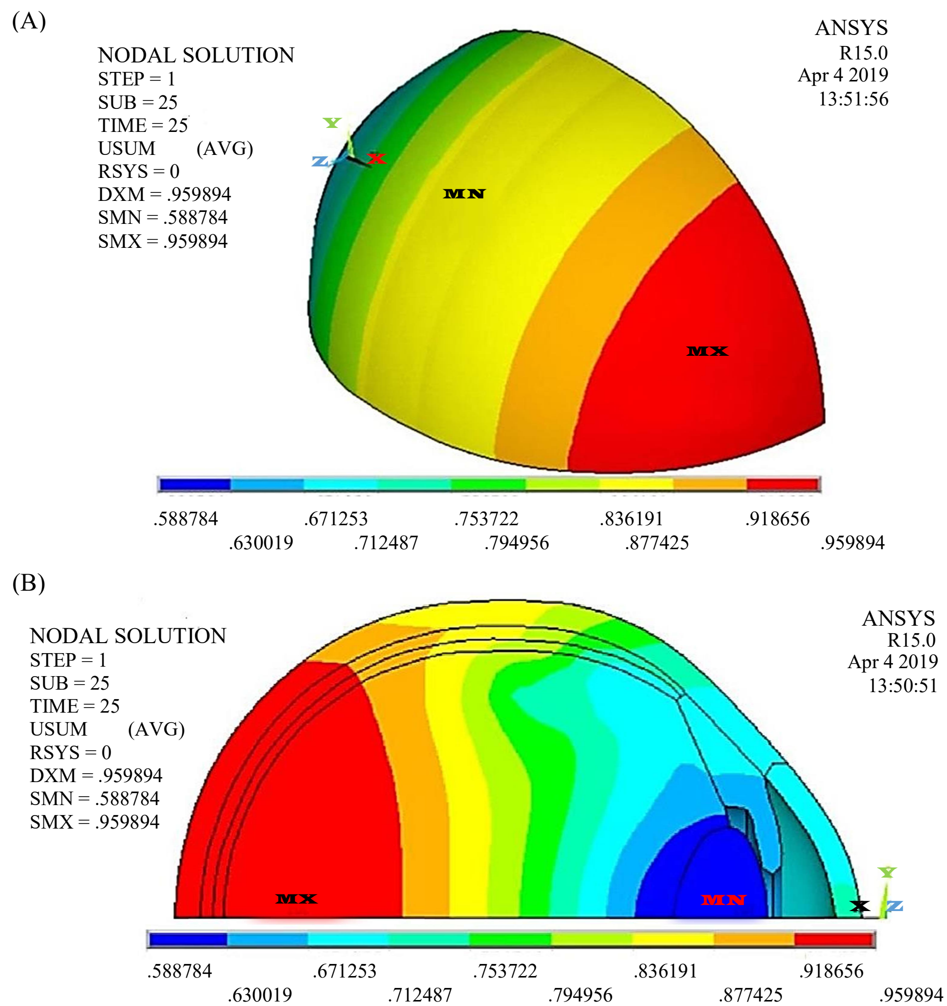

Figure 11 Displacement of eye at 0.2 MPa pressure applied on outer surface of the eye by the ring; isometric view (A), back view (B).

Figure 12 indicates the stresses caused in the eye after 0.2 MPa pressure is applied on outer surface of the ring. (Figure 12 (A)) is the isometric view and (Figure 12 (B)) shows the back view of the eye model. Maximum stress is obtained in the region where ring is in contact with the outer layer of the eye i.e. Sclera.

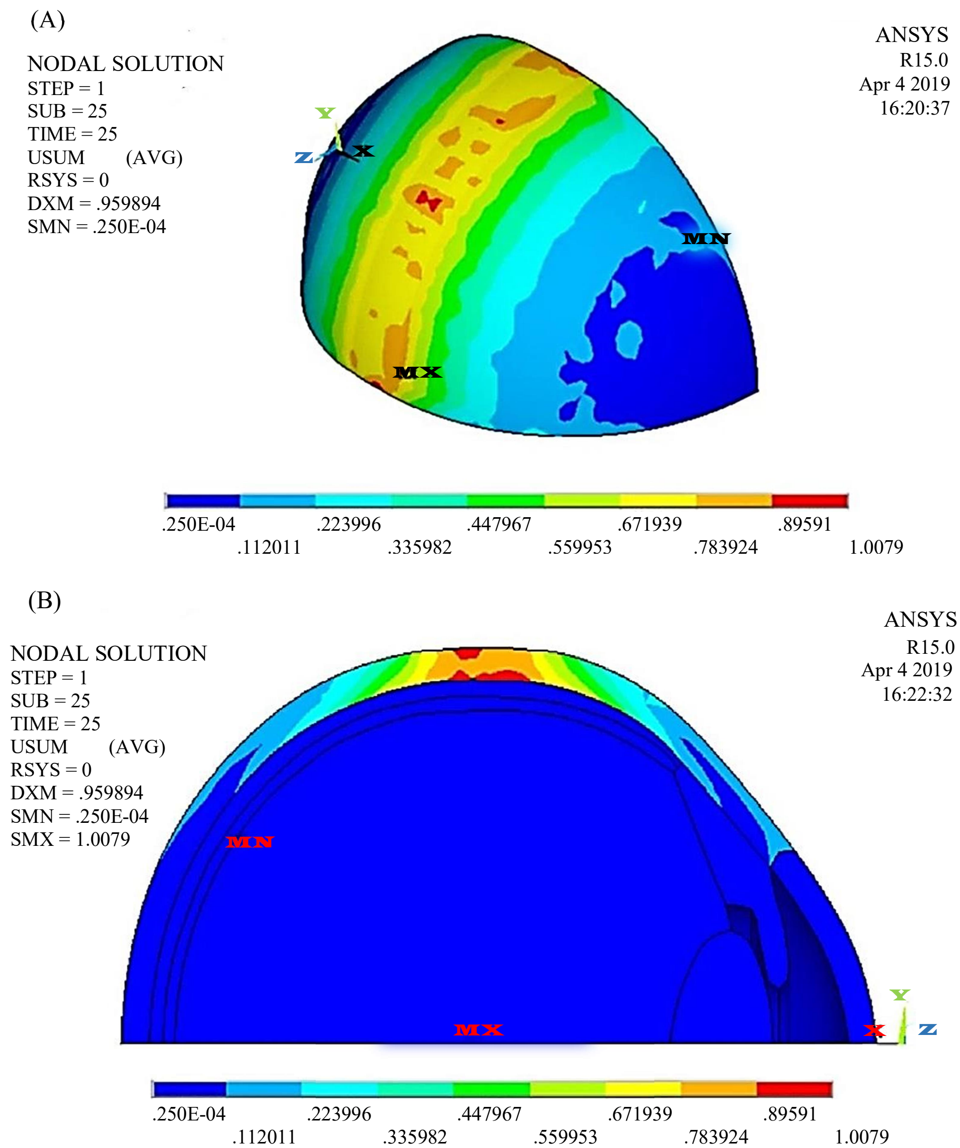

Figure 12 von Mises stress in eye at 0.2 MPa pressure applied on outer surface of the eye by the ring; isometric (A), back (B) view.

The values of displacement sum and von Mises stress are listed below for different components of eye at 0.2 MPa, 0.3 MPa, 0.4 MPa, 0.4 MPa, 0.5 MPa, 0.6 MPa and 0.7 MPa.

Table 5 Displacement values at different pressure values of different eye tissues.

Pressure values (MPa)	Lens (mm)	Ciliary body (mm)	Cornea (mm)	Sclera (mm)	Choroid (mm)	Retina (mm)	Vitreous humor (mm)
0.2	0.5957	0.714	0.7156	0.9525	0.9566	0.9566	0.9598
0.3	0.8936	1.071	1.0735	1.4287	1.4323	1.4349	1.4398
0.4	1.1915	1.428	1.4313	1.905	1.909	1.9132	1.9197
0.5	1.4894	1.785	1.7891	2.3812	2.3871	2.3915	2.3997
0.6	1.7873	2.142	2.147	2.8575	2.8646	2.8698	2.8796
0.7	2.0852	2.499	2.5048	3.3337	3.342	3.3481	3.3596

Table 6 von Mises Stress values at different pressure values of different eye tissues.

Pressure values (MPa)	Lens (KPa)	Choroid (KPa)	Retina (KPa)	Vitreous humor (KPa)	Cornea (KPa)	Ciliary body (KPa)	Sclera (KPa)
0.2	15.1	53	10.28	13.6	61.2	64.7	1157.2
0.3	22.6	78	15.4	20.4	91.8	97.1	1735.8
0.4	30.2	105	20.56	27.3	122.4	129.5	2314.4
0.5	37.7	131	25.7	34.1	153	161.9	2893.1
0.6	45.3	157.5	30.8	40.9	183.6	194.3	3471.7
0.7	52.9	184	35.9	47.7	214.2	226.6	4050.3

For better understanding of the values of displacement sum and von Mises stress in the Table 5 and Table 6, graphs are plotted between pressure and displacement sum or von Mises stress values for different components of eye.

Variations of displacements with increasing external pressure by scleral buckle are presented in (Figure 13 A-C)). The increase in displacement of different human eye components can be observed. Approximately, displacement of Scleral, Choroid, Retina and Vitreous Humor are same (Figure 13 (B)) but, highest displacement values are found in Sclera and lowest in Choroid (Figure 13 (C)).

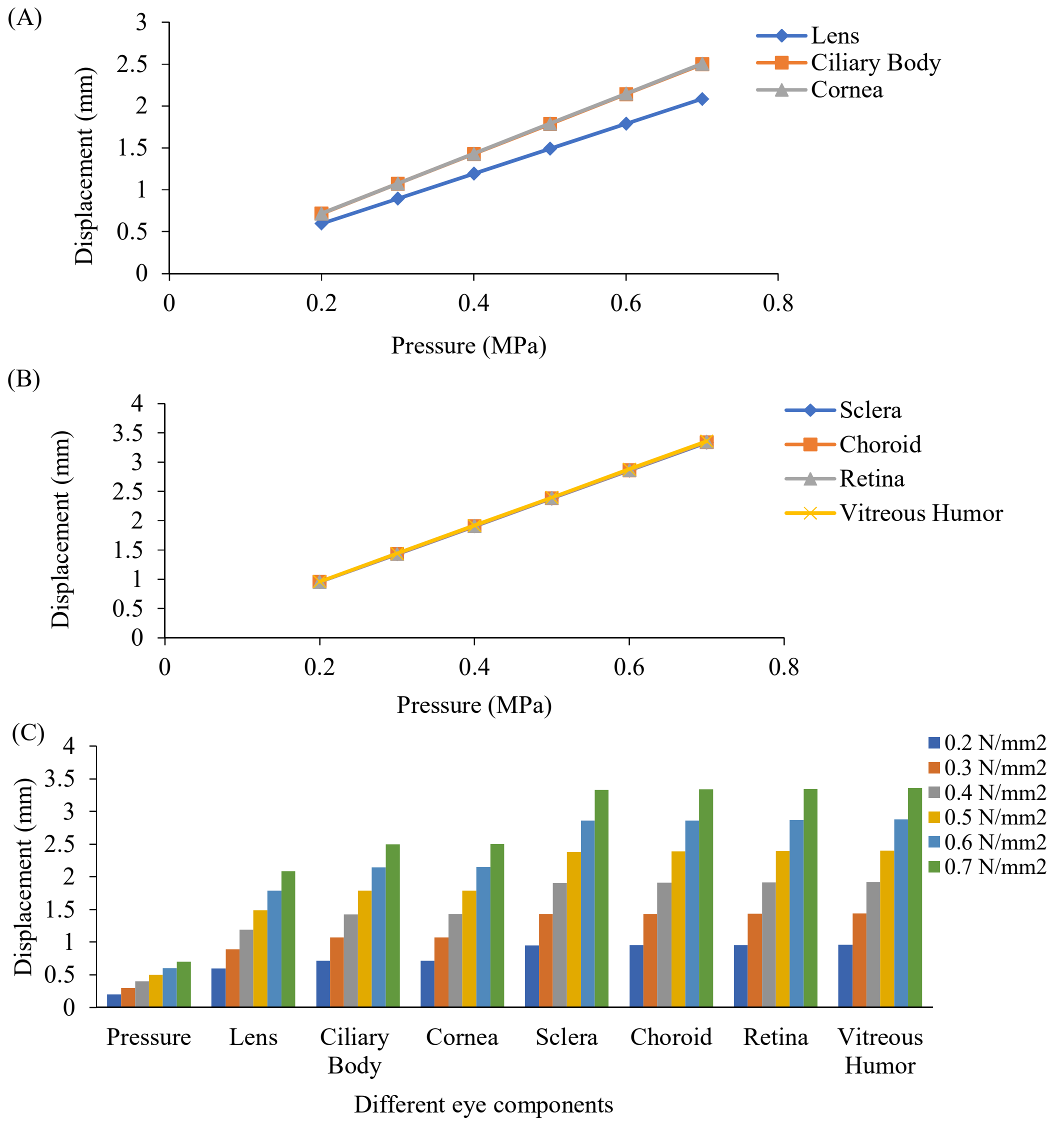

Figure 13 Displacement vs pressure line graph for lens, ciliary body and cornea (A), sclera, choroid, retina and Vitreous Humor (B), different components of eye (C).

The line graphs (Figure 14 (A-C)) represent the displacement-pressure relation for different components of eye and bar graph represents variation in displacement for all the components of eye at 0.2 MPa, 0.3 MPa, 0.4 MPa, 0.5 MPa, 0.6 MPa and 0.7 MPa. Similar types of graph are also plotted for von Mises stress values. The finding and observation on displacements, stresses and strains are

From Stress graphs, the rate of increase in stress of different human eye components can be studied. Stress in Scleral tissue is highest and is lowest in retina.

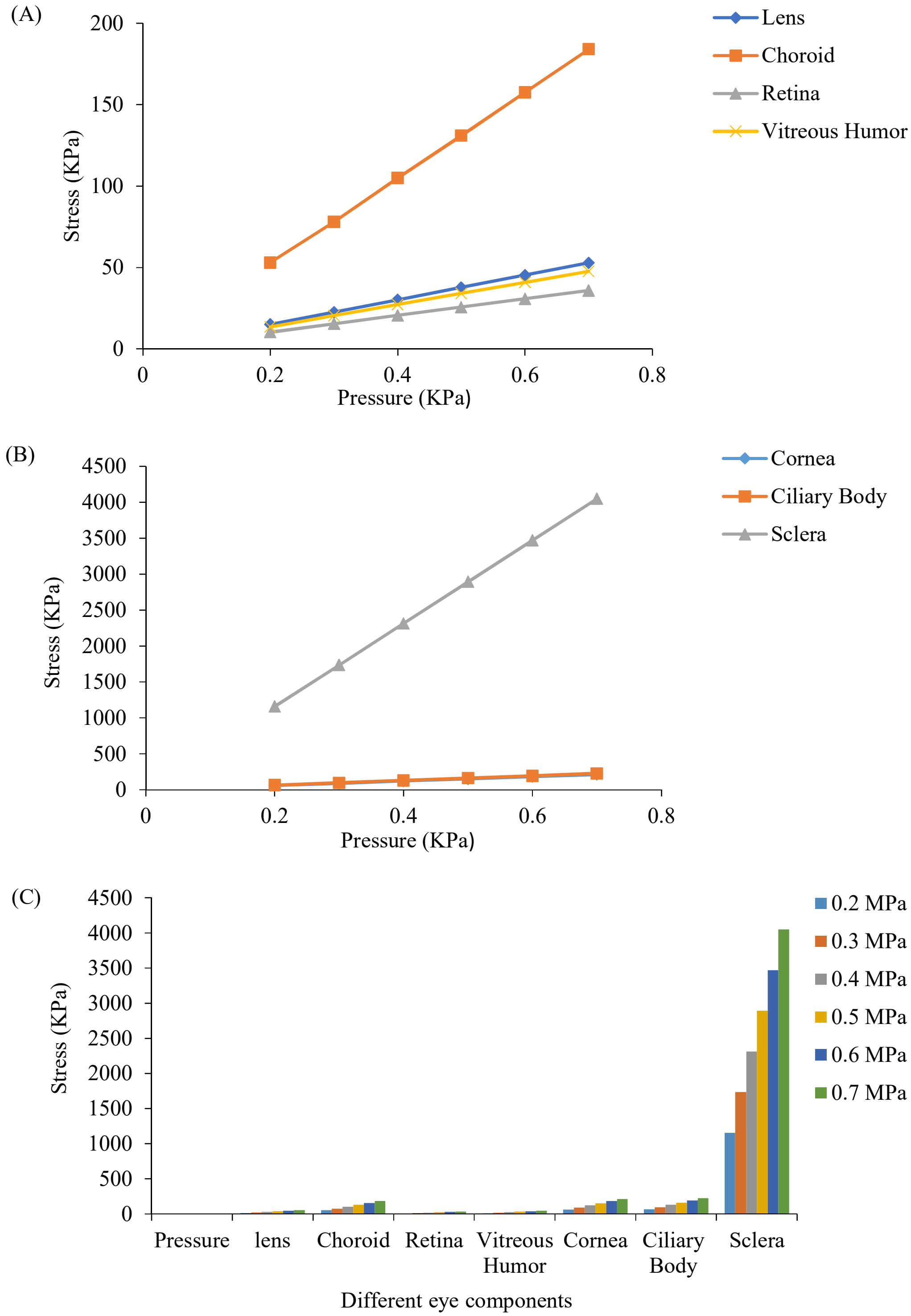

Figure 15 von Mises stress vs pressure line graph for lens, choroid retina and vitreous humor (A), cornea, ciliary body and sclera (B) and different components of eye (C).

The line graphs represent the von Mises stress-pressure relation for different components of eye and bar graph represents variation in von Mises stress for all the components of eye at 0.2 MPa, 0.3 MPa, 0.4 MPa, 0.5 MPa, 0.6 MPa and 0.7MPa.

From the results obtained, highest displacement and stress is found in Vitreous Humor i.e. 3.3596 mm and 4050.3 KPa stress in sclera respectively. The maximum value stress in sclera found in previous study [1] is 412 kPa, this is because considering different indentation instead of buckle pressure on external surface of eye tissue. Lowest displacement and stress is found in lens i.e. 2.0852 mm and 35.9 KPa in retina respectively. The results are well inline with the findings and observations reported in [1,3]. It can be concluded that Sclera will experience highest stress. Hence, during scleral buckling surgery, sclera must be taken care of. Otherwise, it may lead to medical complications. This study also confirms findings of [1] like, maximum stresses from buckle is observed to be located at the edge of the buckle contact on the sclera.

Vitreous humor being a fluid, it is expected to have more displacement than other tissues and maximum stress in the sclera, on the area where ring is found to be in contact with the sclera.

4. Conclusion

By using FEA, the values of pressure exerted by the ring on the eye are interpreted at which the diameter of the eye is equal to the inner diameter of the ring. The pressure values found out are 0.2 MPa, 0.4 MPa, 0.5 MPa, 0.6 MPa and 0.7 MPa. These pressure values are applied on the outer surface of the ring and thus simulating the actual situation. The solution is obtained by applying suitable boundary conditions and loads. The highest displacement of 3.3596 mm for pressure value 0.7 MPa is found in Vitreous humor as expected. A maximum stress of 4050.3 KPa for 0.7 MPa pressure value is found at contact surface of sclera where the ring touches the Scleral outer surface. The results are well in agreement with earlier studies [1,3]. The maximum displacement of 3.3481 mm and a stress of 35.9 KPa at 0.7 MPa pressure is observed on retina typically in the regions of likely detachment. This indicates scleral buckle could facilitate restoration of detachment.

From the displacement graphs for Sclera, Choroid, Retina and Vitreous Humor, it can be concluded that the eye deforms in the posterior region. Because of this deformation in posterior region, the spherical shape of the eye becomes slightly oval in shape. As a result, the light rays converging from the lens will not form image on retina. Thus, it will lead to Myopia (near sightedness) [2].

However, in this study, it is observed that there are excessive values of the physical parameters like displacement and stress caused to some of the eye tissues that leads to myopia like disorders. Similar advanced studies like this one would certainly help ophthalmologists for the better treatment of patients.

Due to ring, the liquid inside the eye will be pushed axially i.e. along the posterior (back portion) and anterior (front portion) region of the eye. The increase in fluid pressure in the posterior region, will impart pressure on Optic Nerve head. Thus, optic nerve being subjected to increase in pressure greater than the normal IOP (12-22 mm Hg), will damage the optic nerve head. Damage to the optic nerve head, will affect the vision of the patient. Depending on the retinal tear, width of the Ring is decided. More the width of the ring, higher will be the increase in IOP, thus, the rate of damaging optic nerve will increase.

Thus, the analysis shows that the Scleral Buckling Surgery may lead to myopia and optic nerve cupping. This research work does not work on the corrective measures taken for the problems aroused during Scleral Buckling Surgery. To account measures for these problems, further exhaustive study of interpretation of stress and displacement values is required which is beyond the scope of this project work. The optic nerve connects the eye to the brain however; model of optic nerve is excluded in this study.

It is established by earlier researchers that scleral buckle surgery can fix the medical abnormalities related to retinal detachments. However, in the present FEA study on this procedure, it is observed that Sclera undergoes the highest stress, which may lead to other issues related other eye tissues and sclera in particular. Therefore, choosing patient specific scleral buckle, with just right size and material behaviour is challenging to ophthalmologists and eye surgeons.

5. References

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