Effect of Various Contact Lenses on Intraocular Pressure and Corneal Biomechanical Properties: A Comprehensive Review

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Abstract: The connection between corneal biomechanical properties (BMP) and intraocular pressure (IOP) has been observed with various type of contact lenses, like soft, rigid, and scleral contact lenses. This study investigated how soft, rigid gas-permeable (RGP), and scleral contact lenses affect corneal biomechanical properties (BMP) and intraocular pressure (IOP). A literature search was carried out using following main topics and related subtopics: corneal BMP, RGP contact lens, soft contact lens, scleral contact lens, the correlation between corneal BMP and contact lens, and the relationship between IOP and contact lens. The literature search includes 60 publications from PubMed, Google Scholar, ResearchGate, Crossref, and Academia search engines. It has been seen that some of the corneal BMP and IOP are being affected by soft contact lenses and RGP, but it depends on the duration of lens wear. Scleral lenses do not have any negative impact on BMP or IOP.

***Keywords**: Soft Contact Lens, Rigid Gas-Permeable (RGP) Contact Lens, Scleral Contact Lens, Corneal Biomechanical Property, Intraocular Pressure.*

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I. INTRODUCTION

The cornea is a durable and intricate biocomposite structure made of unique materials that enable it to withstand both internal and external forces. It relies on collagen fibers for support, striking a balance between strength, durability, and flexibility.[1] The collagen fibrils are arranged in layers in the cornea, improving the mechanical properties according to the direction of the fibrils while remaining sufficiently malleable when subjected to stress, increasing the strength of the tissue without compromising its ability to withstand various biomechanical loading capacities.[2] The structure of the cornea, especially in the stromal region, affects its macroscopic, microscopic and nanomechanical domain, dividing the tissue into uniform areas that combine all the biomechanical power and the ability to assimilate information to prevent damage when necessary.[3] The relationship between stress and strain is crucial for understanding how tissues react to applied forces.

The elastic modulus, often referred to as Young's modulus, reflects the stiffness of the tissue and its ability to withstand deformation. The role of rigid materials in force transmission and control efficiency is important.[4] The cornea is dome-shaped and is subjected to three types of loads or stresses piercing, crushing, and transmural pressure.[5-7]

The hardness, strength, ductility and rigidity of the human cornea are maintained by its biomechanical properties (BMP), including its thickness and collagen fiber cross-linking.[5] Accurate measurement of these properties remains a challenge in optometry and ophthalmology. The current discussion on corneal biomechanics is largely based on in vitro tests like strip extensometry and inflation testing.[8] The elasticity of the cornea involves the storage of the energy resulting from the stretching and deformation of collagen molecules. The viscosity is related to the energy dissipated as collagen fibers slide past each other. The viscoelastic properties of corn allow stress and absorb energy, preventing premature biomechanical failure. Viscoelastic tissue exhibits a property called hysteresis, which measures the delay between the application of force and its response, as well as the delay between the termination of force and its return.[9] These elements complicate the complete understanding of the cornea's biomechanical behavior.[5,6]

Refractive errors are a frequent and widespread issue in eye health, being the leading contributor to vision loss around the world.[10,11] Soft contact lenses serve multiple functions, including enhancing appearance(cosmetic) and providing medical treatment, in addition to correcting vision problems caused by refractive errors.[12] They are composed of soft, flexible plastic materials that permit oxygen to reach the cornea.[13] Soft contact lenses provide enhanced comfort over rigid gas-permeable (RGP) lenses.[14] The latest generation of soft lens materials includes silicone hydrogels, which allow for increased oxygen transmission compared to standard hydrogel contact lenses.15,16,17]

RGP lenses are made from rigid materials that typically include silicone/acrylate and fluoro-silicone/acrylate.[18] This lightweight material allows high-dK oxygen to pass directly through the lens.[19] RGP contact lenses are the best for irregular corneas, high astigmatism, and keratoconus, but they also have many limitations, like initial comfort, environmental problems, and requiring a fitting inventory.[20,21]Scleral contact lenses create opportunities for practical, non-surgical visual rehabilitation at all levels of pathology.[6,22] These RGP lenses extend across the cornea and rest on the sclera, making them more comfortable than traditional RGP lenses.[23] Scleral contact lenses are the most suitable choice for individuals with keratoconus who cannot tolerate regular contact lenses or experience poor vision with standard corneal rigid lenses.[24,25]

II. METHODS

- *Source of Data and Search Strategy*

An extensive review was conducted to evaluate how different types of contact lenses influence intraocular pressure and biomechanical properties (BMP) of the eye. The literature search comprised various databases, such as PubMed, Google Scholar, ResearchGate, Crossref, and Academia.The search approach involved using a combination of specific keywords and terms: ‘soft contact lenses’, ‘RGP contact lenses’, ‘scleral contact lenses’, ‘corneal biomechanical properties’, and ‘intraocular pressure (IOP).’ The selected articles needed to discuss how different types of contact lenses impacted corneal BMP and IOP (Table 1).

- *Inclusion and Exclusion Criteria*

We selected studies that examined the impact of contact lenses on intraocular pressure (IOP) and biomechanical properties (BMP). The inclusion criteria were: (1) articles published in scholarly journals; (2) written in English; (3) not classified as case reports; and (4) specifically focused on the effect of contact lenses on IOP and BMP. Reviews, commentaries, study protocols, and article responses were excluded from the analysis.

- *Data Extraction and Quality Assessment*

After eliminating duplicate entries, we examined the titles and abstracts to determine which articles qualified for a full-text review. For those that met the inclusion criteria, the quality of evidence was evaluated based on Cochrane’s guidelines for assessing risk of bias and levels of evidence.

III. RESULTS

Sixty-one studies were identified describing the effect of various contact lenses on IOP and BMP.

- *Intraocular Pressure:*

Intraocular pressure (IOP) is the force applied by the internal contents of the eye against the walls of the eyeball.[26] A stable level of intraocular pressure (IOP) is primarily maintained by a balanced interaction between the production of aqueous humor, its drainage, and the episcleral venous pressure. This pressure is evenly distributed throughout the eye, ensuring that the IOP in the vitreous body at the back is equal to that in the aqueous humor at the front.[27] Maintaining proper intraocular pressure (IOP) is crucial for preserving the shape of the eyeball and, consequently, its optical function. Normal IOP typically ranges between 10.5 and 20.5 mmHg.[28] Measuring intraocular pressure (IOP) plays a vital role in the diagnosis and management of glaucoma. As a result, obtaining accurate IOP readings that are not influenced by corneal characteristics is becoming increasingly important. Currently, Goldmann applanation tonometry (GAT) is the most commonly used technique and is considered the gold standard for IOP assessment. However, its accuracy can be influenced by factors like central corneal thickness.[29] Alternative methods for measuring intraocular pressure include non-contact tonometry and Pascal dynamic contour tonometry (DCT).[30] Dynamic Contour Tonometry (DCT) is a relatively new contact technique designed to assess intraocular pressure (IOP) by conforming to the natural shape of the cornea. Unlike other methods, DCT provides readings that are not influenced by corneal thickness or curvature, offering a continuous and direct measurement of IOP.[31]

The Ocular Response Analyzer (ORA) is a non-contact instrument used for quick assessment of the cornea's biomechanical properties.[32] The ORA provides intraocular pressure readings adjusted for corneal properties and measures parameters like corneal hysteresis (CH) and the corneal resistance factor. By incorporating the biomechanical behavior of the cornea, it offers a more refined and accurate estimation of IOP. [33] The ORA provides two distinct intraocular pressure readings: Goldmann-correlated

IOPandcorneal-compensatedIOP.. It works on the principle of non-contact tonometry, using a controlled air puff to flatten the central cornea and measure the required air pressure to determine IOP.[34] The ORA collects biomechanical information of the cornea by measuring the difference between its inward and outward movement in response to an air puff over a span of about 20 milliseconds.[33, 35] The Corvis ST utilizes high-speed Scheimpflug imaging, capturing up to 4330 frames per second to document the anterior segment during critical moments such as first applanation, peak concavity, and second applanation. Recent software advancements have added several new metrics, including maximum inverse radius, deformation amplitude ratios at 1 mm and 2 mm, pachy slope, ARTh, integrated radius, stiffness parameter at first applanation (SP-A1), and the Corvis Biomechanical Index.[36]

- *Impact of Soft Contact Lenses on the Biomechanical Properties of the Cornea and Intraocular Pressure*

The biomechanical properties (BMP) and physical characteristics of the cornea can be altered by wearing soft contact lenses. These changes may occur with both short-term and long-term use. Long-term contact lens wear (more than five years) appears to have significantly reduced corneal thickness by around 30-50 µm. Long-term use of contact lenses is associated with an increase in corneal curvature and surface irregularities, which can be detected through corneal topography.[37] Barış Yeniad et al. showed initial month of soft contact lens wear, the cornea tends to flatten and thicken; however, by the 6th to 18th month, it gradually becomes steeper and thinner. [38] Prolonged use of soft contact lenses also leads to alterations in corneal hysteresis (CH) and corneal resistance. Notably, CH and corneal resistance values show a marked reduction on the first day following lens removal. Even after stopping soft contact lens use for over two weeks, reductions in corneal hysteresis (CH) and corneal resistance factor were observed, while the central corneal thickness remained unchanged.[39] Additionally, several studies have reported that prolonged soft contact lens wear does not significantly influence the biomechanical or physical properties of the cornea..[40, 41] According to A. Peyman et al., no notable changes were found in corneal biomechanical properties after one month of soft contact lens wear. However, regression analysis revealed a significant correlation between the lengths of the first and second applanation (A1 and A2) and the deformation amplitude (DA).[42] Additionally, after one month of wearing toric soft contact lenses, the average corneal hysteresis (CH) decreased by 0.4 mmHg compared to the measurement taken after one week, while both central corneal thickness and average keratometry remained largely unchanged. [43] Changes in corneal biomechanical properties are influenced by various factors, including the material composition of soft contact lenses (such as silicone hydrogel or hydrogel), their design (spherical or toric), and their power. [44] Research by N. Mishra et al. demonstrated an increase in corneal hysteresis (CH) following the use of spherical soft contact lenses, whereas CH showed a decline after three months of toric soft lens wear. [45] Furthermore, first- and second-generation silicone hydrogel lenses provided greater biomechanical stability compared to monthly hydrogel lenses over a three-month period..[46] Several studies have also indicated that intraocular pressure (IOP) tends to decrease following both short-term and long-term soft contact lens wear, with significant reductions noted after 10 to 20 days of continuous use.[47, 48]

- *Impact of Rigid Gas-Permeable Contact Lens on the Biomechanical Properties of the Cornea and Intraocular Pressure*

Variations in corneal thickness following short-term use of rigid gas permeable (RGP) contact lenses have been reported, influenced by factors such as lens material, diameter, fitting approach, and duration of wear. Studies have noted an increase in corneal thickness ranging from 1.2% to 4.4% after six hours of RGP lens wear, depending on the lens's central thickness and fit. However, no significant change in average central corneal thickness has been observed after eight hours of continuous wear. Interestingly, while an increase in central corneal thickness is typically seen during the first month of RGP lens usage, prolonged daily wear over six months tends to result in corneal thinning. [49] Alterations in keratometric readings and the spherical components of the anterior corneal surface have also been observed following the use of RGP contact lenses. These keratometric changes tend to be more pronounced in eyes with advanced keratoconus compared to those with moderate forms of the condition. Despite these variations, corneal progression parameters—such as corneal thickness, posterior keratometry, and indices of irregular astigmatism—generally remained stable.[50]

Intraocular pressure (IOP) plays a contributory role in the adherence of RGP contact lenses to the corneal surface, making the cornea more prone to lens impression and subsequent lens fixation. The occurrence of lens adherence in the early morning hours appears to be associated with the physiological peak in IOP observed in many individuals with normal eye pressure. This suggests a potential link between elevated IOP during

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sleep and the tendency for RGP lenses to become immobile overnight.[51]

- *Impact of the Scleral Contact Lens on the Biomechanical Properties of the Cornea and Intraocular Pressure*

Extended use of scleral contact lenses does not negatively impact intraocular pressure (IOP) or corneal biomechanical parameters (BMP) in eyes with either normal or ectatic corneas. Macedo-de-Araújo et al. reported no significant differences in corrected IOP, Goldman-equivalent IOP, corneal hysteresis (CH), or corneal resistance factor. However, Goldman-equivalent IOP and corneal biomechanical values were consistently lower in patients with irregular corneas ($p < 0.001$). Additionally, a significant decrease in the fluid reservoir thickness was observed, with an average reduction of 186.29 µm in eyes with irregular corneas compared to 175.32 µm in those with regular corneas ($p < 0.001$). Moderate to strong negative correlations between IOP and corneal biomechanical parameters were also noted in individuals with regular corneas, except for corrected IOP, where this relationship was not significant.[52]

Multiple studies have independently assessed the impact of scleral contact lenses on different anterior segment structures as well as on intraocular pressure (IOP). Furthermore, research has investigated changes in the optic nerve head to determine whether elevated IOP resulting from scleral lens wear could induce structural alterations. Optical coherence tomography[53] has proven to be a reliable tool for assessing changes by measuring the Bruch's membrane (BM) opening in relation to the minimum ring amplitude. Its diagnostic performance, in terms of sensitivity and accuracy, is comparable to that of retinal nerve fiber layer evaluations. However, some studies have reported inconsistent findings. Some studies have observed a decrease in this parameter after six hours of wearing contact lenses, while others have not observed any changes within the same period or after scleral lens removal. Moreover, studies have not identified any significant association between the Bruch's membrane (BM) opening relative to the minimum ring amplitude and intraocular pressure (IOP). Scleral lenses rest on multiple ocular structures, potentially inducing morphological alterations, particularly in the cornea. Extended wear of scleral lenses—exceeding eight hours—can result in approximately 2% corneal edema, attributed to the lens's central thickness and the fluid reservoir, which together hinder adequate oxygen transmission. Nonetheless, this level of edema remains lower than the physiological edema of about 4% typically observed during sleep. No detectable changes were observed in the trabecular-iris angle during the first four hours of lens wear or immediately after lens removal. The most significant compression from the lens occurs in the adjacent conjunctival and episcleral tissues within the landing zone, while compression in the scleral tissue itself remains below 2%. Despite these effects, the structural changes observed in the scleral tissue were minimal.[54]

The precise mechanism underlying the increase in intraocular pressure (IOP) during scleral lens wear is not fully understood, though it may be associated with compression at the lens landing zone affecting aqueous humor outflow pathways. Short-term scleral lens use has been shown to cause a modest rise in IOP and minor changes in iris–ciliary angle measurements (Figure 1). However, these effects do not appear to be clinically significant in individuals with otherwise healthy eyes [55] Wearing scleral lenses has been associated with an increase in intraocular pressure (IOP), particularly when the lenses are improperly applied over a prolonged period. Since IOP cannot be measured while the lenses are worn, Goldmann Applanation Tonometry (GAT) has detected a slight rise in IOP—approximately 1 mmHg—immediately after lens removal. The pneumotonometer[56] has demonstrated a strong correlation between corneal and scleral IOP readings in healthy individuals, with scleral IOP measurements typically about 6 mmHg higher than those taken at the cornea. One proposed mechanism for this IOP elevation involves suction forces; however, the theory that a loss of the fluid reservoir beneath the lens during lens settling causes sub-atmospheric pressure and subsequent pressure increase is considered unlikely. Alternatively, the pressure exerted by the scleral lens on the episcleral veins and nearby anatomical structures—such as the iridocorneal angle and Schlemm's canal—may impede aqueous humor outflow, thereby increasing IOP. Using scleral lenses with larger diameters might help mitigate this compression by distributing the lens weight over a wider area. Conversely, smaller diameter lenses may induce greater intraocular fluid displacement due to tangential flattening, potentially leading to higher IOP. Additionally, lenses with larger diameters and fittings that maintain lower initial fluid reservoirs centrally have been observed to exhibit less settling over time..[57]

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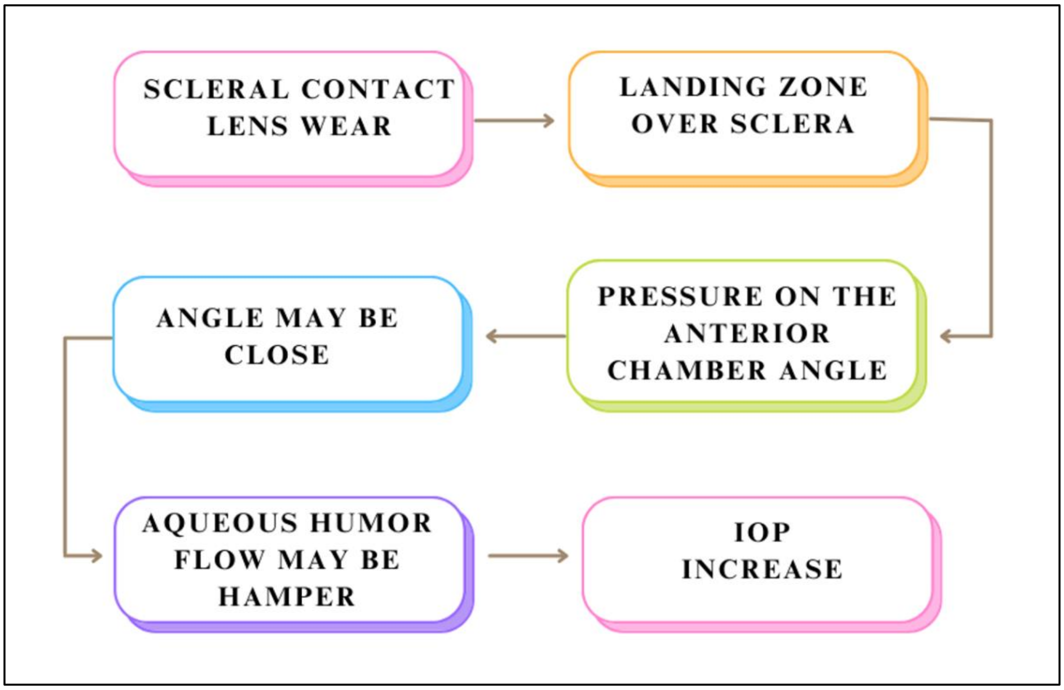

Fig 1: Flowchat for IOP Increases with Scleral CL

In recent years, the use of scleral contact lenses has become increasingly common; however, there is still no established agreement regarding the optimal central corneal clearance for fitting these lenses. Studies have reported considerable variation in central clearance when using lenses of identical design but with different sagittal heights, with greater sagittal heights resulting in increased clearance. This central clearance is a key factor influencing oxygen permeability to the cornea and overall ocular health. Some evidence indicates that maintaining central clearance below 200 µm may be necessary to minimize the risk of corneal hypoxia. .[58, 59]

Short-term use of scleral lenses has been associated with a mild increase in intraocular pressure (IOP) along with minor alterations in central corneal thickness, the iridociliary angle, and Schlemm's canal. However, these changes are generally considered clinically insignificant in individuals with healthy eyes. In cases of trachomatous trichiasis, a moderate correlation has been observed with peripheral arterial tonometry, although the two measurement methods cannot be used interchangeably in patients wearing scleral lenses. Furthermore, long-term wear of corneoscleral lenses for up to one year does not appear to significantly affect the cornea's viscoelastic properties.[60, 61]

IV. CONCLUSION

Soft contact lens wear influences the biomechanical properties (BMP) of the cornea in both short-term and long-term use. Notably, a significant reduction in corneal thickness has been observed with lens wear. While minor alterations in corneal hysteresis (CH) have been reported, these changes are generally not statistically significant. The decrease in corneal thickness may also contribute to a slight reduction in intraocular pressure (IOP), although the extent of this effect remains minimal. To fully understand the long-term impact of soft contact lens wear on corneal biomechanics and IOP, further comprehensive studies are required.

In summary, variations in corneal thickness associated with short-term rigid gas permeable (RGP) contact lens wear are influenced by factors such as lens material, diameter, fitting characteristics, and duration of wear. While an initial increase in corneal thickness may occur, prolonged daily use generally leads to corneal thinning. Additionally, fluctuations in intraocular pressure (IOP) may affect lens adherence to the corneal surface, potentially causing lens imprinting or reduced mobility, particularly during early morning IOP peaks. However, current evidence is lacking regarding the specific effects of RGP lenses on corneal hysteresis (CH) and IOP in both short- and long-term use. Therefore, further studies are necessary to clarify how RGP lens wear influences corneal biomechanics and IOP.

In the present study, we observed that extended use of scleral contact lenses does not appear to negatively affect IOP or the biomechanical properties of the cornea. Nonetheless, individuals with irregular corneas may demonstrate lower IOP values and altered biomechanical behavior. The precise mechanism behind IOP elevation during scleral lens wear remains uncertain, but it is likely related to the mechanical compression of anatomical structures involved in aqueous humor outflow. Although short-term scleral lens wear may lead to minor increases in IOP and subtle changes in ocular parameters, these effects seem to lack significant clinical

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relevance in healthy populations. To establish a clearer understanding, further research is warranted to investigate the relationship between both short- and long-term scleral lens use and its influence on IOP and corneal biomechanics.

Table 1 Tabular Literature Summaries from a Scoping Review on the Relationship of Intraocular Pressure (IOP) with Corneal Biomechanical Biomechanical Properties)BMP).

Authors	Journal Name	Corneal Thickness	Corneal Hysteresis	Corneal Resistance Factor	Corneal curvature	Intraocular Pressure
1. Liu Z et al.	American Academy of Ophthalmology	Reduced			Increase	
2. S. Xu et al.	IOVS	Constant	Decreased	Decreased		
3. Barış Yeniad et al.	Lippincott	Reduced			Increase	
4. A. Kissner et al.	IOVS		Constant	Constant		
5. Somayeh Radaie-Moghadam et al.	Journal of Ophthalmic & vision Research	Constant	Decreased	Decreased	Constant	
6. Macedo-de-Araújo RJ, Seco RM, González-Méijome JM et al.	Cont Lens Anterior Eye	Constant	Decreased	Constant		Decreased

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Abbreviations: IOP = Intraocular pressure, BMP = Biomechanical properties, RGP = Rigid gas-permeable, DCT = Dynamic contour tonometry, ORA = Ocular response analyser, CH = Corneal hysteresis, DA= Deformation amplitude, BM = Bruch's membrane, SPA'1 = Stiffness parameter at the first applanation, GAT = Goldmann's applanation tonometry

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