TECHNICAL UNIVERSITY OF CLUJ-NAPOCA

ACTA TECHNICA NAPOCENSIS

Series: Applied Mathematics, Mechanics, and Engineering
Vol. 63, Issue Special, October, 2020

INNOVATIVE TRIZ-BASED APPROACH TO PREVENT CLDE SYMPTOMS IN SILICONE-HYDROGEL EYE CONTACT LENSES

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Abstract: *Since the invention of a very first eye contact lens in 1887, as an alternative to conventional glasses, drastic changes has been implied into the material, structure, shape and other parameters of eye contact lenses. Nowadays eye contact lenses are used by over 150 million people worldwide for corrective, cosmetic and therapeutic purposes. The most popular modern eye contact lenses are made from silicon and hydrogel. Silicon makes up the channels inside the lens through which oxygen, water and nutrients are going to the cornea, while hydrogel as a highly hydrophilic gel adsorbs water and maintains soft structure of the lens which is necessary for normal functioning of the eye. Although both components are necessary in the eye contact lens, they cause negative effects such as increased evaporation due to porous structure and water adsorption from tear film, that is critical for maintaining moisture on the eye surface. Combination of these effects ultimately lead to the occurrence of contact lens-related dry eye syndrome (CLDE), that is experienced by about 50% of contact lens wearers. Our goal is to apply TRIZ-based approaches to develop an innovative structure of eye contact lenses that will prevent the occurrence of CLDE. After thorough study of the mechanisms triggering CLDE the technical contradiction and physical contradiction of the core problem were identified. Cause-effect chain Analysis (CECA) and function diagram played the key role in transitioning from the problem to the possible solutions. Various ideas of improvement were suggested through the specifics of application of different TRIZ tools in accordance with ARIZ85C. Conclusively, TRIZ can be a potential breakthrough if incorporated as a solving method for medical, biological, biochemical and other related areas.*

Key words: *CLDE, silicon-hydrogel lens, ARIZ85C, TRIZ.*

1. INTRODUCTION

1.1 History of contact lens.

The popularity of contact lenses (CL) is growing exponentially and is known to be used by over 150 million people worldwide[1] for various applications from therapeutic to cosmetic purposes[2].The first concept of historical eye contact lens begins in 1508, when Leonardo DaVinci depicted possible shapes of lenses. Later in 1632 lenses that would cover the entire front eye were suggested by Rene Descartes, and in 1827 glass as a protective material, was recommended for lens by John Herschel. In 1880s Adolph Fick, Eugene Kale, and August Miller independently designed the very first scleral CL that was heavy and uncomfortable to wear. Since then the CL has undergone tremendous changes in size, shape and structure. Glass, plastic, polyvinyl alcohol (PVA) [3,4], non-gas-permeable polymethyl methacrylate (PMMA), hydroxy ethyl methacrylate (HEMA), a hydrogel polymer[5], silicone [6] and hydrogel were used as material for CL. Manufacturing techniques had undergone a long path of changes from handmade process and polishing precise laser cutting. In 1999 scientists created a silicone hydrogel contact lens through copolymerization process, using monomers of silicon and hydrogel. They are currently used by most eye contact wearers[7]occupying 65% of eye contact lens market[8].

1.2 Silicone hydrogel lenses

Silicone monomers are making up channels (pores) within the eye lens network allowing higher oxygen permeability which is critical for the comfort and prevention of hypoxia-related complications, including dry eyes and corneal edema [9,10]. However, silicone is an inherently hydrophobic material and therefore tends to cause discomfort due to lack of wetting and subsequent roughness. Hydrogel on the contrary, is a hydrophilic material as it can hold a significant amount of water (up to 90%) due to electrochemical polarity and thus, provides CL with such properties as wettability, biocompatibility, optical characteristic, and mechanical strength [11], maintaining eye lens soft structure. However, hydrogel CL leads to cornea swelling[8] as its oxygen permeability is significantly lower than that of silicone. Silicone hydrogel lenses has significantly reduced negative changes in corneal homeostasis, while prominently extending time of CL wearing [12]. Unlike conventional hydrogel lenses, silicone hydrogel lenses' oxygen permeability does not depend on its water content, but rather on the number of the channels within the lens[13]. Despite the significant improvements achieved, the dropout for CL wear has reached up to 50% for the last several years[14]. One third of all eye contact wearers are reported to suffer from contact lens-related dry-eye syndrome (CLDE), and 70% of wearers had contact lens discomfort (CLD)[15]. Moreover, the risk of infection is high due to physical contact between lens and eye regardless of material[12].

1.3 Risk factor analysis of CLDE development

Under normal circumstances, without the presence of eye contact lens, frontal area of the eye is always covered with a complex unique thin fluid layer - tear film (TF) (3-6 μm) that conducts multiple function including lubrication nutrition and protection. TF consists of three layers. Outermost layer is a lipid layer serves as barrier between the environment and the eye[16]. Its main function is to retard evaporation. Middle layer is an aqueous layer contains electrolytes and nutrients and provides oxygen and nutrients to the eye, while flushing away epithelial debris, toxins, and foreign bodies[17]. Inner layer is a mucus layer promotes wetting of the cornea[18]. Over the time tear film is influenced by gravitational force, friction force, dispersion forces that change its stability. Tear film evaporates, adsorbs (osmotic transfer of tears across the cornea), and drainages becomes thinner and might eventually break forming dry thus it needs to be restored frequently. In a healthy eye tear-film breakup does not occur due to frequent blinking (25 times per minute) during which tear fluid is distributed over the eye and maintains its stability. As the tear break up time is about 15 to 50 seconds the interblink time is much shorter compared to the time of rupture of the tear film.

CL is a permeable fluid saturated porous medium of constant, which has a typical center thickness of at least 70μm that gradually decreases peripherally. Any eye contact lens substantially changes both oxygen permeability and biophysical and biochemical properties of the tear film [19]. Once CL is inserted in the eye it immediately divides TF into two thinner parts with decreased volume of fluid[20]: pre-lens and post lens TFs[21].Subsequently tear break up time becomes shorter [22]. Sufficient amount of post-lens and pre-lens TF is required in order to maintain the overall health of the eye. Dry-eye syndrome, discomfort and/or lens adhesion occurs due to contact-lens dehydration and of post-lens tear-film depletion.[22] which is tied to evaporation drainage and absorption. Firstly, due to the process of evaporation aqueous layer becomes thin and reaches the point where outermost lipid layer start interacting with the hydrophobic components of CL, forming lipid deposits on its surface, which in turn leads to instantaneous breakup of the tear film [1]. The impaired stability of tear film results in enhanced evaporation of pre-lens TF. Loss of water in pre-lens TF is then replaced by fluid coming from the posterior surface and through the matrix of the lens, thereby draining the post-lens TF. Secondly, hydrophilic components of the eye contact lens attract water molecules[23] from both pre and post TFs, therefore contributing the thinning process. Additionally, CL itself undergoes alterations in diameter, thickness[24], refractive power and on-eye movement[25] when water content is decreased. This leads to friction between eyelid and ocular surface, discomfort sensations, dryness, and redness of the eye[26] (Fig.1) that can be deteriorated by certain environmental factors such as low humidity and rising airflow [27]. Although various lens modifications where suggested including new chemical modification techniques, plasma treatment, modified lens surface to adhere polyelectrolyte monolayers, improved anti-microbial properties of the lenses[28] via melamine-derived peptide (Mel4) attachment, lesser silicon content via application of longer silicate chains, hydrogen bonding of water molecules to form naturally water-loving contact lens[29]. The process of eye contact lens evolution remains questioned by scientists that continue developing new designs, biocompatible coatings, and finding new materials to meet growing requirements of contact lens wearers[19].

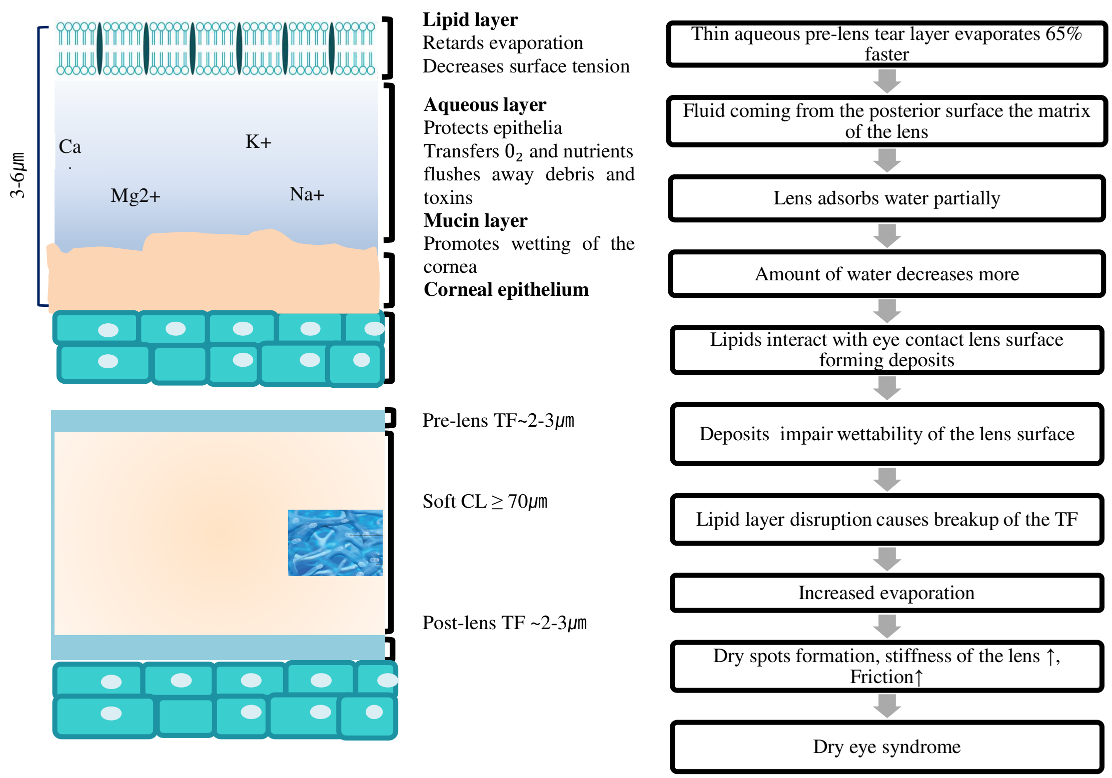

Fig. 1. Mechanism of CLDE development.

2. TRIZ

TRIZ or Theory of Inventive Problem Solving is a constructive methodology for generating ideas and solving problems, which were extracted from thousands of previous known inventions[30] by great inventor, writer and independent scientist Genrich Altshuller. He believed that inventive process can be structured, and the best solution can be created by applying a chain of strategies, therefore making the invention a systematic process not a spontaneous one[31]. Nowadays TRIZ is known worldwide as an innovation technology that is actively used in various disciplines and industries[32,33]. ARIZ (The Algorithm for Inventive Problem Solving) is an analytical tool within TRIZ that provides a set of precise systematic steps, practical step by step instructions and various tools for developing a solution for complex innovative problems[34]. ARIZ consists of nine parts as described in a case study. In this study we attempt to resolve the problem of CLDE symptoms via application of ARIZ85C.

3. CASE STUDY: DEVELOPING MODIFICATIONS IN SILICONE-HYDROGEL EYE CONTACT LENSES TO PREVENT CLDE SYMPTOMS.

3.1 Part 1 Analysis of the problem

At the beginning the problem is usually wide and uncertain: there is a negative effect/problem, but it is unclear how to solve it. Numerous types of tools can be applied in this step including Function analysis, Flow analysis, Cause-Effect Chain Analysis, Evolutionary Trends analysis etc. to determine a conflicting pair - object and tool; and identify the conflict between them - technical contradiction. Wearing silicon hydrogel CL causes dryness in the eye. Thus, the eye contact lens must be somehow changed to prevent this undesired effect. Silicone component of CL is forming so-called channels that provide oxygen permeability but increase evaporation. Hydrophilic hydrogel provides the wettability of CL but causes absorption of water from the TF promoting CLDE. Since the CLDE is triggered in two different ways by two components of the CL (hydrogel initiates absorption of the tear film and silicone contributes excessive evaporation), two Cause-Effect Chain Analyses were conducted to identify the detailed mechanism of how each problem occurs and to understand the key disadvantages of the analyzed system [35] was conducted, and the target disadvantages were linked to its fundamental causes as it is shown in Figure 2A and 2B.

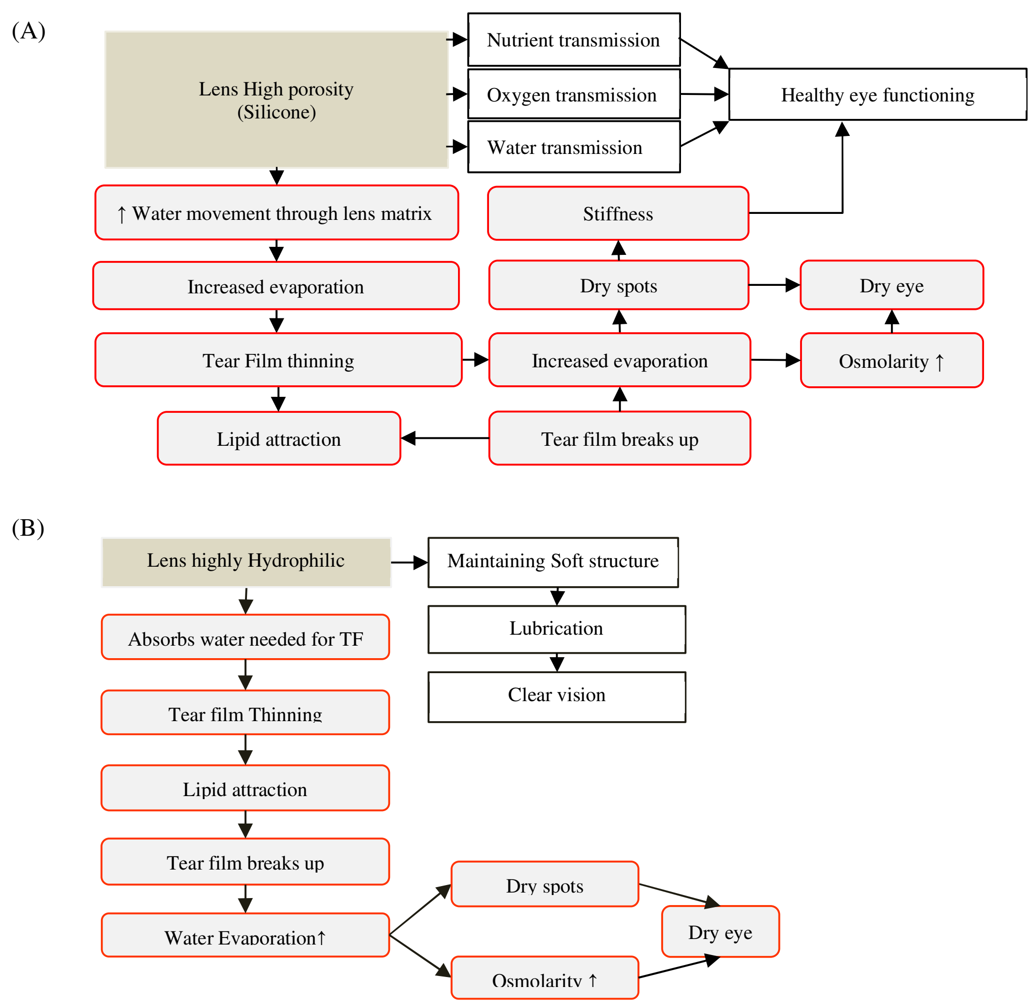

Fig. 2. .CECA analysis for CLDE symptoms. (A) Diagram of 1st Cause-effect Chain Analysis regarding high porosity; (B) Diagram of 2nd Cause-effect Chain Analysis regarding hydrophilicity.

The system of the problem was divided into critical components as it is demonstrated in Table 1.

Determining specifications of actions performed by one component (object) that leads to alteration of an attribute of another component (tool) plays a key role in identifying main functions contributing in undesirable effect as illustrated in figure 3A and 3B. Based on this analysis technical contradictions in silicone and hydrogel were identified.

Table 1

Components of the eye-CL system

Components of the system	
Contact lens	Aqueous layer of TF
Pores (channels) in eye contact lens	Mucin Layer of TF
Hydrogel of eye contact lens	Light wave
Pre-lens TF	Retina
Post-lens TF	Cornea (eye surface)
Lipid layer of TF	

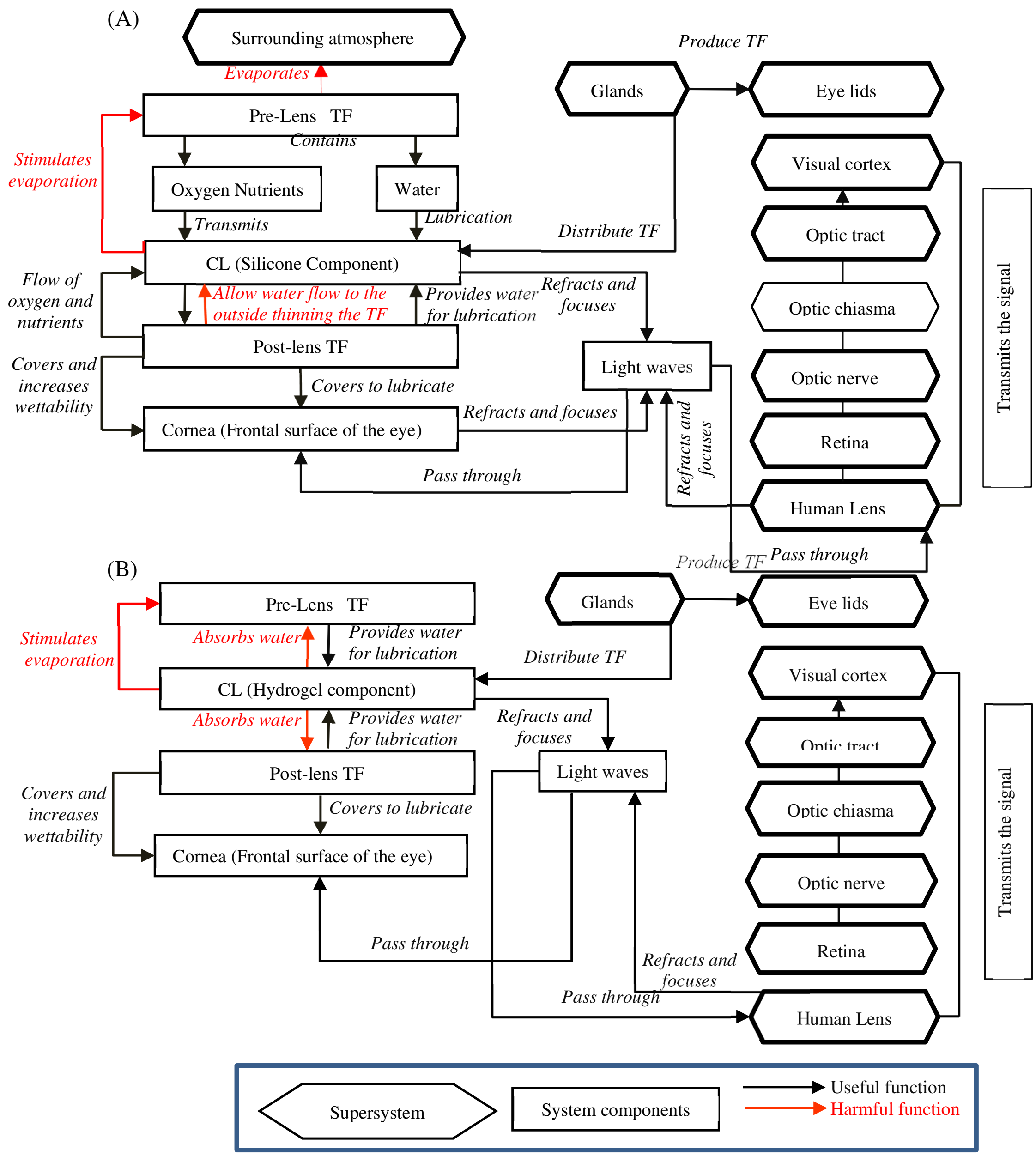

Fig. 3. Function analysis diagram. (A) Function analysis diagram 1 based on silicone component Illustration of useful and harmful functions of the components of the system and supersystem. (B) Function analysis diagram 2 based on hydrogel component. Illustration of useful and harmful functions of the components of the system and supersystem.

Technical Contradiction for silicone component (TCSC)

TCSC 1) High porosity allows healthy functioning of the eye due to flow of oxygen water and nutrients through the channels in the lens(+) but increases the evaporation rate and causing dry eye due because when the pre-lens tear film evaporates the water from post-lens tear film moves out through the lens to compensate(-).

TCSC 2) Low porosity does not increase the evaporation rate and does not cause dry eye due because when the pre-lens tear film evaporates the water from post-lens tear film cannot move out through the lens to compensate (+) but it does not allows healthy functioning of the eye due to lack of oxygen water and nutrients (-).

Technical Contradiction for hydrogel component (TCHC)

TCSC 1) Highly hydrophilic lens allows healthy functioning due to lubrication and soft structure (+) but adsorbs water from tear film causing dry eye (-).

TCSC 2) Low hydrophilicity of lens adsorbs less water from tear film (+) but does not maintain soft structure and lack of lubrication (-).

3.2 Part 2 Analysis of the problem's model.

A specified narrow area of the conflict (Operative Zone OZ) and period of the conflict (Operative Time OT) is determined. Operative zone 1 includes silicone channels within the matrix of CL. Operative zone 2 is a hydrogel mass that fills up a space in CL around silicone channels. (Fig. 4A, 4B) Operative time OT for both problems starts from the moment when eye contact lenses are inserted in the eye and ends once CLs are removed.

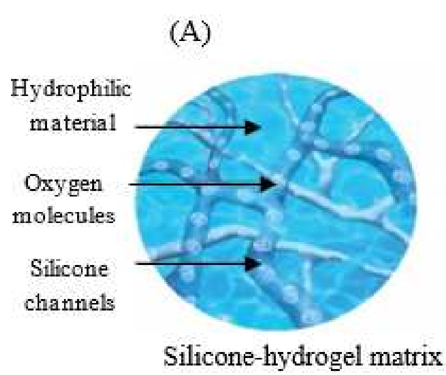

Fig. 4A. Structure of silicone-hydrogel matrix in CL;

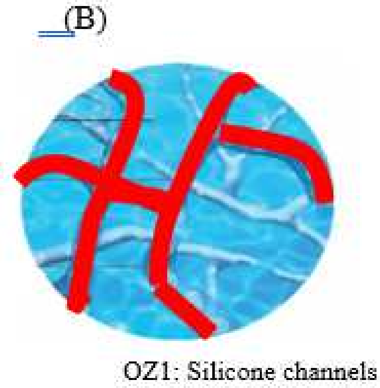

Fig. 4B. Operative zone 1. Silicone channels highlighted with red color are determined as OZ for the oxygen flow/evaporation rate contradiction;

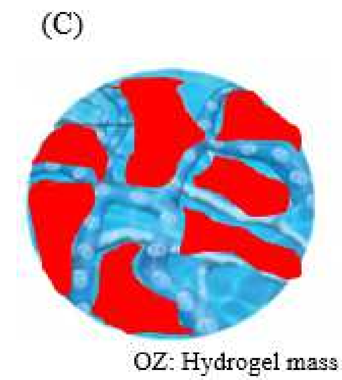

Fig. 4C. Operative zone 2. Hydrogel mass highlighted with red color is determined as an OZ for the wettability /adsorption contradiction.

3.3 Part 3. Formulation of the Ideal Final Result (IFR).

Defining IFR allows us to instantly focus on best solutions. The most desirable result is achieved when the problem "fixes itself". Once IFR is defined it reveals a Physical Contradiction (PC) a situation that emerges when a certain characteristic of a material object must have two different values at the same time to deliver a required result.

Determination of IFR and PC for silicone component:

[*IFR1*]: X-element, without complicating the system and without causing harmful phenomena, does not allow or eliminates (Movement of the water from post lens towards the outside and therefore increased evaporation.) during OT (wearing lenses) within OZ while maintaining oxygen and nutrient flow through the lens matrix.

[*PC1*]: CL must allow Oxygen flow and thus oxygen transmissibility during OT within OZ while restricting the movement of Post-lens TF outside and therefore increased evaporation. Hence CL must allow the flow through the silicone channels, but it must not allow the flow and that is the core of PC.

Determination of IFR and PC for hydrogel component:

[*IFR2*]: X-element, without complicating the system and without causing harmful phenomena, does not allow or eliminates (Water adsorption and therefore TF thinning.) during OT (wearing lenses) in OZ while maintaining lubrication and soft structure of the lens.

[*PC2*]: CL should be able to maintain soft structure and provide lubrication, but CL should not adsorb water therefore causing TF thinning and causing dry eye. The soft structure of the CL is provided due to its hydrophilicity however the same quality is causing TF thinning.

3.4 Part 4. Utilization of outside substances and field resources

To depict the core of the problem a substance-field scheme was created (Fig. 5A) It is clear that CL is affected by mechanical force from the eye surface (cornea), components of TF and oxygen. Harmful effect occurs when water from post-lens TF (substance 3) moves through the channels (substance 1) of CL. This approach reveals the details of relationship between elements in the form of substances and forces (fields) affecting them. Figure 5B demonstrates the relationship of hydrogel component of CL and surrounding elements involved. As the hydrogel (substance 1) is hydrophilic it absorbs water from both post-lens TF (substance 3) and pre-lens TF (substance 2).

Among 5 classes of 76 Standard Solutions class1 and class 5 may be considered as sources for potential solution [36]. For instance, class 1 dictates that system must be improved with no change or little change, thus the lens material should remain the same (no change), although the degree of hydrophilicity on surface can be increased for the lubrication (little change). Class 5 is focused on strategies for simplification and improvement and for our case the lens can be improved if the portion of liquid (substance) would be added to the inner surface of the lens, and this it would melt once put on the eye, instantly providing extra moisture. However, these modifications do not eliminate all problems contributing to the dryness of the eye.

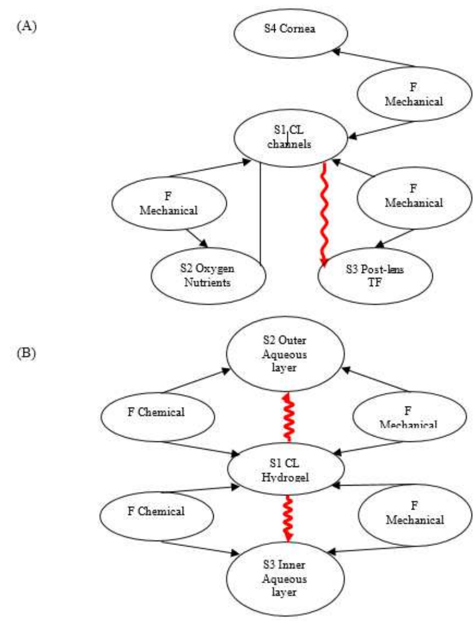

Fig. 5. Su-field analysis. (A) Su-field diagram depicting harmful interaction between S1 and S3 related to silicone component (channels) of CL. (B) Su-field diagram depicting harmful interaction between S1, S2 and S3 related to hydrogel component (channels) of CL.

Clearly two components of the CL (silicone and hydrogel are playing essential role in the normal functioning, however each of them to a certain extent contribute to the occurrence of the dry eye symptoms in two different ways: silicone stimulates evaporation, hydrogel provokes absorption. Both of these mechanisms should be solved and thus it is reasonable to classify them into two problems. After determining the exact cause and location of the problems we are trying to find potential solution in accordance with the rules [37] applied in finding potential solution in ARIZ as follows:

Problem 1: Porosity of CL is provided by silicone component, which is required for oxygen transmissibility, but it promotes evaporation of tear film and therefore causes dryness in the eye.

Use what is in the system: Change the lens pores location- more in the center less at the edges. Such positioning of the pores will maintain the oxygen transmissibility while making the edges of the lens soft due to sufficient amount of hydrogel and thus allowing the lens floating necessary for smooth functioning between eye surface and CL.
Use empty space: N/A
Use disappearing substance: Eye drops
Resource utilization: N/A
Insert substance related to field: N/A
Insert field: N/A

Problem 2: Hydrophilicity of CL is provided by hydrogel component and is responsible for maintaining soft structure of the CL, however hydrogel absorbs water and thus triggers dry eye symptoms.

Use what is in the system: Make lens more hydrophilic on the surface. If the surface only is hydrophilic the amount of absorbed water will be less than if the entire lens was hydrophilic.
Use empty space: N/A
Use disappearing substance: Eye drops
Resource utilization: N/A
Insert substance related to field: Add liquid coating.
Insert field: N/A

In this case as the suitable solution has not been found we continued the search

3.5 Part 5. Utilization of informational data bank

This step is aimed to use already invented knowledge. 76 Standard Solutions, 40 Inventive principles, existing solutions from analogous tasks in combination with database of technological effects: physical effects, chemical effects, biological effects, mathematical effects need to be considered.

In our case the collection of 40 Inventive Principles based on the theory of technical systems [38], thousands of patents collected[39] were used in the process of developing the final solution. Firstly, the parameters that require improvement were determined and corresponding deteriorating parameters of each TC were selected. In particular improving parameters include: parameter 6 area of non-moving object corresponds to the area of the CL that causes the problem of dry eyes; parameter 23 waste of substance, in this case is the amount of tear film that is either over-evaporated (TCSC1) or over-absorbed (TCHC1); parameter 26 amount of substance is the amount of hydrogel and silicone that affects the qualities of CL; parameter 31 Harmful side effects are the dry symptoms that need to be eliminated.

Deteriorating parameters are as follow: parameter 7 volume of moving object is the volume of liquid that moves though the pores or is being absorbed by hydrogel; parameter 15durability of moving object is the time during which lens can be worn comfortably without experience of dry eye symptoms; parameter 26.Amount of substance is the amount of , also corresponds to the tear film, as its volume needs to be increased. Potential solutions were detected in the contradiction matrix which provides a systematic access to the most frequently used inventive principles to resolve a specific type of a technical contradiction. In the Contradiction Matrix, the particular type of a contradiction is selected by the pre-defined standard engineering parameters as shown in Table 2.

Table 2

Inventive Principles selected from Contradiction Matrix.

Deteriorating Parameter / Improving Parameter	7 Volume of moving object	15 Durability of moving object	26 Amount of substance
6 Area of non-moving object	-	-	2,18,40,4
23 Waste of substance	1,29,30,36	28,27,3,18	6,3,10,24
26 Amount of substance	15,20,29	3,35,10,40	-
31 Harmful side effects	17,2,40	15,22,33,31	3,24,39,1

Among determined inventive principles the most suitable were proposed to solve TC of current case:

Principle 1 Segmentation. This principle suggests dividing an object into independent parts, make an object easy to disassemble or increase the degree of fragmentation or segmentation.

Principle 3 Local quality principle insinuates the change of object's structure from uniform to non-uniform, alter an external environment (or external influence) from uniform to non-uniform, make each part of an object fulfill a different and useful function.

Principle 4 Asymmetry principle implies the change of the shape of an object from symmetrical to asymmetrical or if an object is asymmetrical, increase its degree of asymmetry.

Principle 29 Fluid, Pneumatics principle is based on replacing the solid parts of the object into gas or liquid parts (e.g. filled with liquids, air cushion, hydrostatic, hydro-reactive).

Principle 40 Composite Materials. This principle recommends changing materials from uniform to composite (multiple) materials [40, 41].

Problem-solving ideas were generated in accordance with the principles selected as shown in Table 3.

Physical contradictions were identified in step 3. PC is a state where two conflicting requirements are placed upon a single parameter of the system. There are three methods of resolving physical contradictions: Separating Contradictory Demands, Satisfying Contradictory Demands (in case if separating the demands is impossible then both of them should be satisfied) or Bypassing Contradictory Demands [35]. These approaches should be used respectively in order as illustrated in Figure 6.

Table 3

Potential problem-solving ideas generated via corresponding Inventive Principles.

Segmentation	Locate areas for hydrogel and silicone
Local Quality	More silicon in the center
Fluid, Pneumatics	Liquid coating of the lens
Asymmetry	More Hydrogel on the outer part of CL
Composite Materials	Silicone and Hydrogel and Liquid

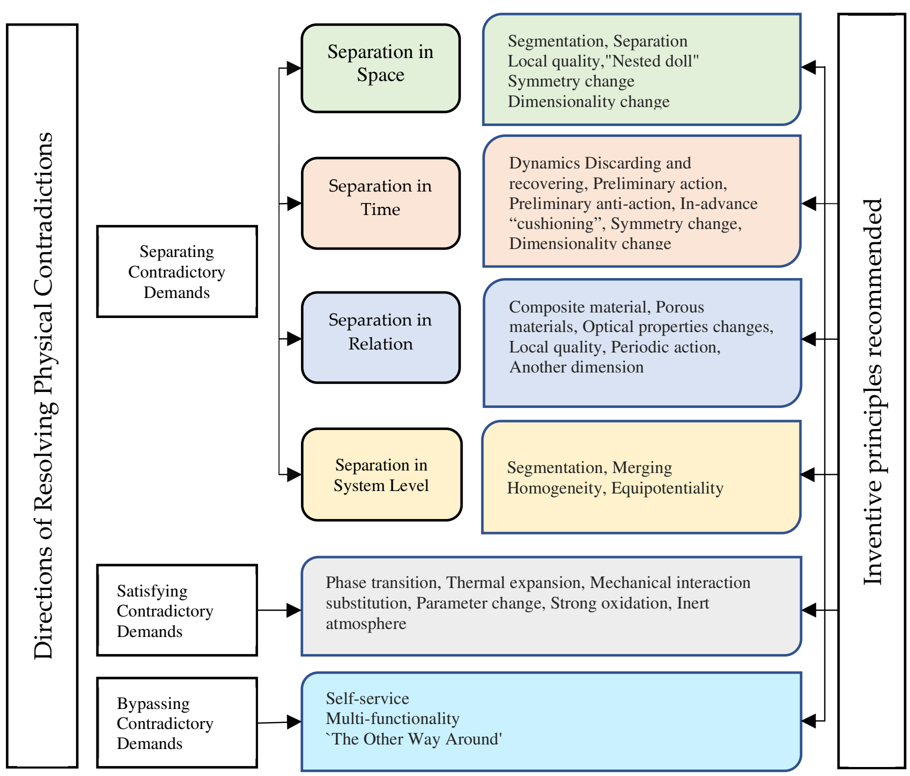

Fig. 6. Methods of elimination of Physical Contradictions and Inventive Principles recommended for their resolution.

In current case PC can be eliminated through separation in space by changing the shape of channels via modification of molecular structure of silicone within CL. Another way of separation is locating hydrogel mostly on the surface of the lens; however, this measure will significantly decrease the oxygen transmissibility.

Final solution

Our ultimate solution comprises a combination of suggested inventive principles (local quality, segmentation and asymmetry) by solving technical contradiction aiming the improvement of the structure of CL in prevention of CLDE symptoms. According to our final ideas CL can be modified as follows: (Fig.7).

1) Silicone distribution within the lens is concentrated in the center thereby providing more channels and higher oxygen flow towards the center of the cornea (local quality).

2) Silicone distribution is radiating from the center to the outer parts of the CL mimicking sun rays.

3) Hydrogel is mostly filling up the space between "sun rays" of silicone channels (segmentation).

4) Content of hydrogel is gradually increasing from the center towards the outer parts of CL (asymmetry) instead of being equally distributed throughout the matrix of the CL.

Although any type of CL decrease the amount of oxygen flow to the cornea selected distribution of silicone and hydrogel will provide higher oxygen transmissibility as the molecules of oxygen passing through the center of the lens will spread radially due to its low viscosity[42]. Similarly, oxygen that passes through the "sun-ray-like" shaped silicone will flow out gradually covering the parts of the cornea that are covered with hydrogel-concentrated surface of the lens. Once the molecules of pre-lens TF flow through the silicone channels, they will be attracted by the molecules of post-lens TF due to strong bonding tendency between water molecules [43] thereby providing oxygen supply for cornea. As the hydrogel matrix is condensed in the outer part of CL it will maintain the soft structure and provide enough lubrication for the smooth movement of the lens on the eye surface. It is important that in such kind of CL the distribution of silicone and hydrogel is steady and does not have sharp-switch spots. Therefore, both silicone and hydrogel molecules are scattered throughout the matrix of the lens, only its concentration varies in different areas of the CL. Such distribution will provide necessary hydrophilicity of the lens; however, the absorption of the tear film will be significantly lower, only being intense in the areas between "sun rays". At the same time silicone channels concentrated within the "sun rays" will provide necessary oxygen, as the molecules of oxygen will go through the pores towards the surface of the eye and spread under the hydrogel-concentrated part of the lens as well. Meanwhile the evaporation process will occur only within the areas of high concentration of silicone, therefore, general rate of evaporation will be essentially diminished.

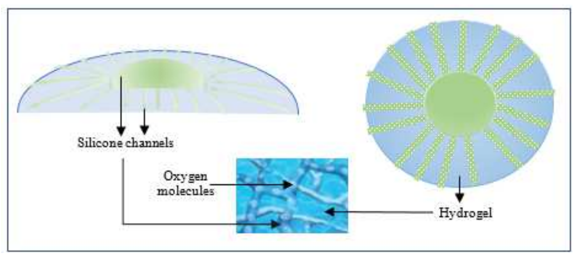

Fig. 7. The diagram of CL modified using TRIZ tools. Distribution of Silicone and Hydrogel follows specific pattern, where silicone content is concentrated in the center and gradually radiates towards the outer parts of the lens. Hydrogel mass is mostly located in the outer parts of the lens steadily decreasing as it converges to the center.

3.6 Part 6. Change or reformulate the problem.

If the problem has still not been solved, it is recommended to go back to Step 1 and reformulate the problem in respect to the supersystem. This looping process can be done several times until the solution is found. In this case there is no need to reformulate the problem.

3.7 Part 7. Analysis of the method that eliminated the Physical Contradiction.

To evaluate the obtained solution a pre-defined questionnaire must be answered as shown in Table 4.

Table 4

Evaluation of the final solution.

Does the solution provide the main demand of IFR (element by itself…..)?	Yes
IS PC eliminated with the solution and which one	Yes, PC1 and PC2
Does the system have at least one well controllable element? Which one?	Yes
Is th solution applicable for one-cycle task in real life with many cycles?	Yes

3.8 Part 8. Utilization of found solution.

An identical solution has not been found in the patent database. Separation in space, Local quality and Asymmetry principles were applied in finding the final solution. The total goal of Part 8 implies the consideration of possible adoption of the final solution general principle in other contexts. Such attempt comprises an extensive range of different aspects such as the evaluation of super-system alterations [43]. Determination of the opportunities for further application of the obtained idea can be examined when the following possible approaches are considered: using reversal principle, combining every performing option with each subsystem, replacing one state of matter to another, modifying the location of subsystem, etc.

3.9 Part 9. Analysis of steps that lead to the solution.

Practical implementation of the final idea has not been put under the test, but it is required to determine the difference between theoretical conclusion and empirical efficiency of the problem solution.

Ultimately, Part 9 is aimed to analyze the problem-solving process in order to deepen the information fund on which ARIZ is built [44]. Each problem solved by ARIZ should increase a person’s creative potential. However, this analysis is out of the scope of this paper.

4. CONCLUSION

Application of TRIZ tools had provided a way of an organized algorithm of thinking to convert the non-typical problem into a typical one. ARIZ-85C stipulates a strong accurate understanding of the key problem and elements involved. Moreover, the problem-solving process developed in accordance with TRIZ offers extensive variations of solutions and requires a shorter period and fewer attempts than usual. This paper presented a deeper level of integration of TRIZ concept into CL industry by linking the technical principles and biological mechanisms of human eye. This case study displays a technological innovation by illustrating the capability of incorporating ARIZ as a problem-solving tool in the medical sector.

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Abordare inovativă bazată pe TRIZ pentru prevenirea simptomelor CLDE în lentilele de contact cu silicon-hidrogel

Rezumat: De la inventarea primei lentile de contact oculare în 1887, ca alternativă la ochelarii convenționali, au avut loc modificări drastice asupra materialului, structurii, formei și altor parametrii ai lentilelor de contact oculare. În zilele noastre, lentilele de contact oculare sunt folosite de peste 150 de milioane de oameni din întreaga lume pentru scopuri corective, cosmetice și terapeutice. Cele mai populare lentile de contact moderne sunt realizate din silicon si hidrogel. Siliconul alcătuiește canalele din interiorul lentilei prin care oxigenul, apa și nutrienții merg spre cornee, în timp ce hidrogelul, ca gel puternic hidrofil, adsorb apă și menține structura moale a lentilei, care este necesară pentru funcționarea normal a ochiului. Deși ambele componente sunt necesare în lentila de contact oculară, acestea provoacă efecte negative cum ar fi evaporarea crescută datorită structurii poroase și adsorbția apei din filmul lacrimal, ceea ce este esențial pentru menținerea umidității pe suprafața ochilor. Combinarea acestor efecte duce în cele din urmă la apariția sindromului de ochi uscat legat de utilizarea lentilelor de contact (CLDE), care este experimentat de aproximativ 50% din purtătorii de lentile de contact. Scopul nostru este să aplicăm abordări bazate pe TRIZ pentru a dezvolta o structură inovatoare a lentilelor de contact oculare care să prevină apariția CLDE. După studierea amănunțită a mecanismelor care declanșează CLDE, au fost identificate contradicțiile tehnice și fizice ale problemei de bază. Analiza lanțului cauză-efect (CECA) și diagrama funcțiilor au jucat rolul esențial în tranziția de la problemă la soluțiile posibile. Au fost sugerate diverse idei de îmbunătățire prin specificul aplicării diferitelor instrumente TRIZ în conformitate cu ARIZ85C. În concluzie, TRIZ poate fi un potențial proces dacă este incorporat ca metodă de soluționare pentru domeniile medical, biologic, biochimic si altele.

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