Benefits and New Features of a Modern International Internet Database "IOLCon" for Updated and Optimized IOL Constants and IOL Specifications

Vorteile und neue Funktionen der modernen internationalen Internetdatenbank „IOLCon" für optimierte IOL-Konstanten und IOL-Spezifikationen

Introduction

Cataract surgery has a history of about 2800 years [1, 2]. Harold Ridley's invention of the intraocular lens in 1949 set a milestone in cataract surgery, supplying patients with a more or less satisfactory refractive implant for the first time [3]. In the following 70 years, cataract surgery, IOL technology, and biometry have developed enormously. The invention of optical biometry in 1999 [4] has again fundamentally changed cataract surgery. The introduction of the first optical biometer, the Zeiss IOLMaster, and Prof. Wolfgang Haigis' (University Würzburg, Germany) ULIB database of formula constants (http://ocusoft.de/ulib/) paved the way for this most successful new technology. In parallel, the number of IOL manufacturers, as well as IOL models and their technical capabilities (e.g., aspheric, multifocal, EDOF, and toric IOLs) have multiplied, making it more difficult for ophthalmic surgeons to maintain a clear overview of all the available options.

Furthermore, more precise biometry results translate into better refractive outcomes after cataract surgery and this in turn leads to more demanding patients, especially when it comes to, e.g., modern, well-informed post-LASIK patients facing their cataract surgery. These highly demanding cataract patients put ophthalmic surgeons under pressure for an optimal refractive outcome of their surgery. This leads not only to the need for suitable, modern biometry but also to appropriate IOL calculation formulae for these special cases, because former standard schemes may fail.

IOL power calculation formulae can be categorized into two groups: regression formulae and theoretical formulae. Regression formulae, like SRK and SRK II, are now obsolete. With these formulae, the use of an "A constant" was introduced, which should adapt the formula to a specific lens type by nullifying the mean or median refraction error, and with the SRK II formula, in addition, adjusting the formula to long and short eyes. Today, numerous modern theoretical formulae based on geometrical optics are used instead, e.g., published formulae like SRK-T, Holladay 1, Hoffer-Q, and Haigis, as well as unpublished, commercial formulae like Barrett Universal 2 and Holladay 2 and, furthermore, Hill RBF, which is based on analyzing multiple postsurgical empirical data. Such formulae regard the eye as a system of two lenses (the cornea and the IOL) and use the so-called "Effective Lens Position" (ELP) to describe the distance between the cornea and the IOL. This is used for calculating the IOL power and may differ significantly between, e.g., the anterior chamber and meniscus lenses. Specific IOL formulae calculate the ELP differently. The first clinical association of the d-values (where "d" stands for the distance of the cornea apex to the principal plane of the IOL) of the crystalline lenses and the implanted posterior chamber IOLs was published in 1984. According to the formula (6 mm − 1.5 mm = 4.5 mm), initially, the ELP was quantified generally as 4.5 mm, not differentiating for specific IOLs or patients [5]. Later, the ELP was set in relation to the axial length and the corneal radius [5].

The better the ELP can be predicted, the better the IOL power calculation will be. Such modern IOL power calculation formulae meet today's increased demands by surgeons and patients regarding the refractive outcome. They also cater to the availability of most modern IOL concepts (like EDOF or trifocal IOLs) by using optimized constants and even more by constants optimized for an individual surgeon. Optimized constants will most probably differ from the nominal constant provided by the manufacturer, being based on a larger sample of postsurgical data. In combination, modern optical biometry, modern surgical techniques, modern IOL concepts, and modern IOL calculation schemes using optimized formula constants will provide patients and surgeons the best postsurgical outcome and fulfil their expectations regarding today's cataract surgery.

Several options have been provided to support ophthalmic surgeons with an overview of all products and their specifications on a national and international basis. The first internationally available online database ULIB (User Group for Laser Interference Biometry, http://ocusoft.de/ulib/c1.htm), initialized by Prof. Wolfgang Haigis, set a milestone in providing nominal and optimized constants of IOLs, but it provided no other IOL characteristics. From today's perspective, ULIB no longer meets modern requirements, as it focused essentially on the Zeiss biometer and offered only very limited filter functions. Furthermore, it did not offer an open interface: the direct download of data was only possible for the Zeiss IOLMaster. In addition, ULIB has not been updated since 2016. Prof. Haigis, who runs ULIB, passed away in 2019. The website of Dr. Warren Hill (https://doctor-hill.com/physicians/lens_constants.htm) also provides IOL constants – but only for a few selected IOLs. On a national basis, the "IOL-Finder" (https://www.iol-finder.de/) published an-

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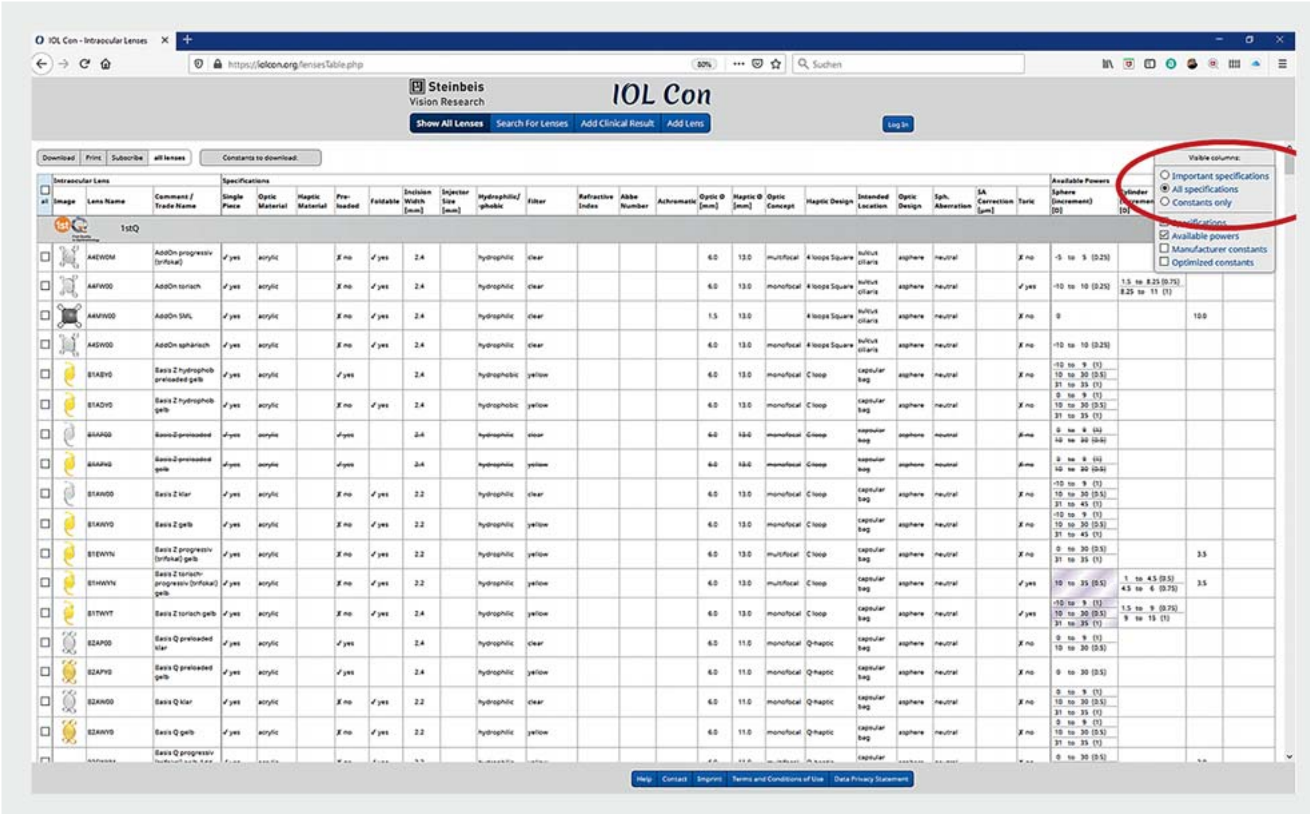


▸ **Fig. 1** Overview of IOLCon's characteristics.

nually by German Biermann Verlag provides IOL characteristics of selected IOLs including nominal, but not optimized constants. Additionally, all IOL manufacturers provide data on their own respective IOLs, including lens characteristics and nominal constants, but not optimized constants.

The aim in designing the internet database "IOLCon" was to fill these gaps by establishing a globally available database providing the most up-to-date IOL characteristics and nominal, optimized characteristics all in one place, and serving ophthalmic surgeons with their individually optimized constants.

Setup and Technical Features

General characteristics of the new "IOLCon" database

Established in 2015, and since its official launch on June 16, 2017, the new international web-based independent encyclopedic database "IOLCon" has been set up at Steinbeis-Transferzentrum Vision Research in cooperation with the Institute of Experimental Ophthalmology at Saarland University. It aims for continuous archiving and automatic, manufacturer-independent optimization of IOL constants for common IOL calculation formulae, and optimization algorithms for published classical "theoretical optical" IOL formulae (SRK/T, Haigis, Hoffer-Q, Holladay 1) have been implemented. Other formulae that are proprietary or non-disclosed such as Holladay 2, Barrett Universal II, or others are not included in IOLCon, as IOLCon does not have the option to evaluate the formula and optimize constants by themselves. In our opinion, formulae that are used by ophthalmic surgeons should be fully disclosed to implement the calculation scheme, to discuss the benefits and drawbacks of the formula, to compare the clinical outcome with a batch process (without manual entering data in any WEB form), and to optimize formula constants with intelligent linear or nonlinear optimization strategies. IOLCon combines the benefits of established databases, presenting technical information of IOLs with an overview over the respective, optimized IOL constants (▸ **Fig. 1**). IOLCon is set up as a user friendly, self-explanatory database independent of specific devices, IOL manufacturers, or surgeons and provided relevant IOL data conveniently. The concept of IOLCon is evolving in cooperation with manufacturers/distributors of IOLs and biometry devices as well as with cataract surgeons [6]. Information regarding the center thickness of the IOL and the shape factor/Coddington factor are desirable additions that are only possible in cooperation with the IOL manufacturers. A certain reluctance of the industry can currently be felt here.

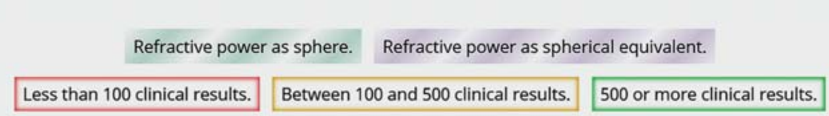
According to an agreement between Haigis and Langenbucher, most data have already been transferred from ULIB to IOLCon.

Technical setup

The platform is based on a PostgreSQL database system. The user interface and the optimization algorithms are programmed in the Hypertext Preprocessor (PHP) language. An interface for biometry devices to enable a standardized data exchange has been defined. Data can be uploaded in CSV, XML, or JSON format. Format examples will be provided by IOLCon. Tabulated results can be prepared with, e.g., Microsoft Excel for more convenient uploading. The IOL characteristics and constants are available via an open data exchange format (XML). XML was chosen as it is a non-commercial database format that is supported by more or less all commercial and non-commercial software packages such as Access, Excel, Paradox, and others. The file exchange format is fully disclosed, and all biometer manufacturers are invited to visit the IOLCon.org website to download the description of the transfer format. Optimization algorithms for published IOL formulae (SRK II, SRK/T, Haigis, HofferQ, Holladay 1) have been implemented. Up to now, the formula constants are optimized differently for formulas with 1 constant (SRKT, Hoffer-Q, Holladay1, and Haigis with optimization of a0 only) or 3 constants. For formulae with 1 constant, the lens power calculation formula was solved for the respective lens constant, and the median of the distribution of individual constants was considered as the “optimized constant”. In contrast, for the Haigis formula, the effective lens position, which is called “d” in the original patent of Professor Haigis, was derived from each data, and a linear regression was set up for axial length and phakic anterior chamber depth considering an intercept. The intercept and scaling of ACD and AL of this regression refer to the optimized a0, a1, and a2. But these optimization strategies do not necessarily yield constants that guarantee the best refractive result, as they do not optimize for the least formula prediction error. Within the last 2 or 3 months, IOLCon implemented and validated for all formulas (SRKT, Hoffer-Q, Holladay1, Haigis with 1 or 3 customized constants) a nonlinear iterative optimization strategy (Levenberg-Marquardt algorithm) with box constrains and weighting factors, which optimizes the formula constants for the root mean

▶ **Table 1** IOL specifications included in IOLCon.

Specifiaction	Explanation
Image	Picture of IOL
Lens Name	Manufacturer's name
Comment/Trade Name	Comment/Brand name
Single Piece	IOL Design (one-piece IOL)
Optic Material	e.g., PMMA, acrylic, silicone
Haptic Material	Material of IOL haptic (in case of difference to optic material), e.g., PMMA, silicone, arylic
Pre-Loaded	Yes/no
Foldable	Yes/no
Incision Width	in mm
Injector Size	in mm
Hydrophilic/-phobic	Material property
Filter	Yes/no and which filter (UV, clear of blue/violet)
Refractive Index	
Abbe Number	
Achromatic	Yes/no (Specific optic design)
Optic Ø	Diameter of optic in mm
Haptic Ø	Diameter including the haptics in mm
Optic Concept	Monofocal, multifocal, trifocal, EDOF
Haptic Design	e.g., plate haptic, C-loop ...
Intended Location	e.g., capsular bag, anterior chamber, iris fixation, sulcus
Optic Design	e.g., spherical, aspherical
Aberration	None, neutral, correcting
SA Correction	Correction of spherical aberration in µm
Toric	Yes/no
Sphere (from) [D] Cylinder (to) [D]	Available powers
Near Addition	In D
Intermediate Addition	In D



▶ **Fig. 2** Information shown in “footnotes” (regarding number of clinical data sets used for IOLCon's optimization and toric notation of IOLs).

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ARTIS Monofokal	Soft Hydrophobic Lens Preloaded	19.3	0.088	0.233	0.2	6.095	2.295	119.74						
ARTIS Toric	Soft Hydrophobic Lens Preloaded	119.3	0.088	0.233	0.2	6.095	2.295	119.74						
Claré	Hydrophilic Lens	118.0	1.59	0.4	0.1	5.26	1.75	118.5						
EAZ-Y	Soft Hydrophobic Lens Preloaded	119.3	1.77	0.4	0.1	6.03	2.33	119.7						
SAL 302A	Soft Hydrophobic Preloaded Lens	118.7	1.32	0.4	0.1	5.51	1.75	118.9	1.1284	0.2394	0.127	5.45	1.677	118.784
SAL 302AC	Soft Hydrophobic Preloaded Lens	118.7	1.32	0.4	0.1	5.51	1.75	118.9	1.1284	0.2394	0.127	5.45	1.677	118.784
Softec 1	Hydrophilic Lens	118.0	0.92	0.4	0.1	5.22	1.47	118.43						
Softec HD	Bi-aspheric Optic	118.0	0.92	0.4	0.1	5.22	1.47	118.43	-0.1302	0.2385	0.169	5.182	1.409	118.362
Softec HDY	Bi-aspheric Optic	118.0	0.92	0.4	0.1	5.22	1.47	118.43	-0.1302	0.2385	0.169	5.182	1.409	118.362

▶ **Fig. 3** Color coding of the quality of the optimized constants (red: fewer than 100 clinical results, yellow: between 100 and 500 clinical results, green: 500 or more clinical results. See also “Footnotes” of IOLCon website).

squared refractive prediction error. Within the upcoming weeks, it is planned to replace the classical optimization procedure by this nonlinear constant optimization strategy to offer constants that promise a lower formula prediction error. And, in addition, in collaboration with Dr. Peter Hoffmann, the Castrop formula has been implemented into IOLCon with 3 formula constants (C, H, and R), which will be also available with the upcoming release of IOLCon. The respective formula constant triplet C, H, and R will also be optimized based on the Levenberg-Marquardt algorithm. In addition, an interface to biometry devices has been defined, enabling standardized data exchange, and this has lately been incorporated into biometry devices by several manufacturers. The server is located within the EU and is subject to German Data Protection law.

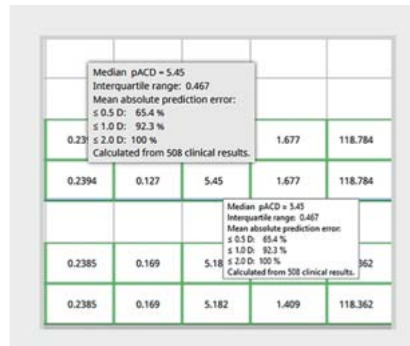
Operability/Usability of the Database

IOLCon is an essential tool for ophthalmology and for the ophthalmologist today: it provides an up-to-date overview of available IOLs with all relevant technical, geometric, and material characteristics, facilitating multiple search options.

Selecting “Show All Lenses” on the main web page displays all available IOLs. Here, the respective IOL model, including the manufacturer information, a graphic symbol of the IOL, and the nominal constants shown on the sales package and on the Instructions for Use are shown.

Through the drop-down menu item “Visible columns”, the information can be refined to “Important specifications”, “All specifications”, “Constants only”, “Specifications”, “Available powers”, “Manufacturer constants” and/or “Optimized constants”. When selecting “Optimized constants” on the right-hand side of the screen, IOLCon’s optimized constants are shown (▶ **Table 1**). The performance of each individual optimized constant, which determines the quality of the constant, can be assessed directly via the website: Color coding, explained in “footnotes” (▶ **Fig. 2**) shows the number of data sets used for a specific optimization: green corresponds to more than 500 clinical results, yellow to between 100 and 500, and red to fewer than 100 clinical results (▶ **Fig. 3**). Also, by moving the cursor across the respective optimization, the user can view the statistical information on which the optimization is based (▶ **Fig. 4**). The notation of toric IOLs is also color coded: green denotes IOLs that refer to “refractive power as sphere”, and violet for “Refractive power as spherical equivalent”) (▶ **Fig. 2**).

The database can be used without the need for registration: By using the “Search For Lenses” function, multiple IOL parameters can be selected. Multiple manufacturers can be chosen by holding the control key (< Ctrl>) while clicking “Search for corresponding Lenses” (▶ **Fig. 5**). The database can be checked specifically for suitable IOL models and the properties of certain models, and an overview of the characteristics of selected IOL models can be compiled. When searching for globally optimized constants in IOLCon, these can be retrieved by selecting the appropriate menu option, e.g., “Constants only”, “Manufacturer constants”, or “Optimized constants” (▶ **Fig. 6**). In addition to these search options, the main menu contains a “Constants to download” drop-down menu allowing for the selection of nominal/optimized constants, ethnicities, bio-



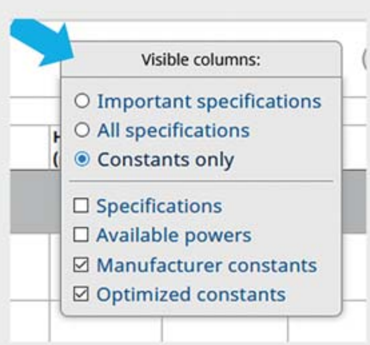
▶ **Fig. 4** Detailed information about the quality of the statistical data of the respective optimization using “mouse over”.

▶ **Fig. 5** IOLCon's search options.

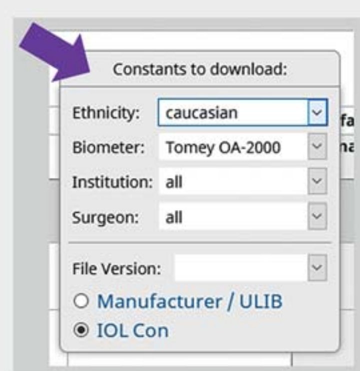
meters, and surgeons or institutions (▶ **Fig. 7**). The "Print" option can be used to generate a convenient printout of technical data and constants.

The registration process can be initiated using the "contact option" (https://iolcon.org/contact.php) or by means of a QR code (▶ **Fig. 8 a, b**).

Optimization of IOL constants can only be reliably realized by using a large number of preoperative biometry data and the respective postoperative refraction results. After registering for IOLCon data entry, two distinct user groups can gain individual password protected access:



▶ **Fig. 6** Options for selecting specific constants.



▶ **Fig. 7** Selection for specific ethnicities, biometers, institutions, or surgeon.

▸ **Fig. 8** **a** Registration request via contact option of the website; **b** QR code leading to IOLCon's website.

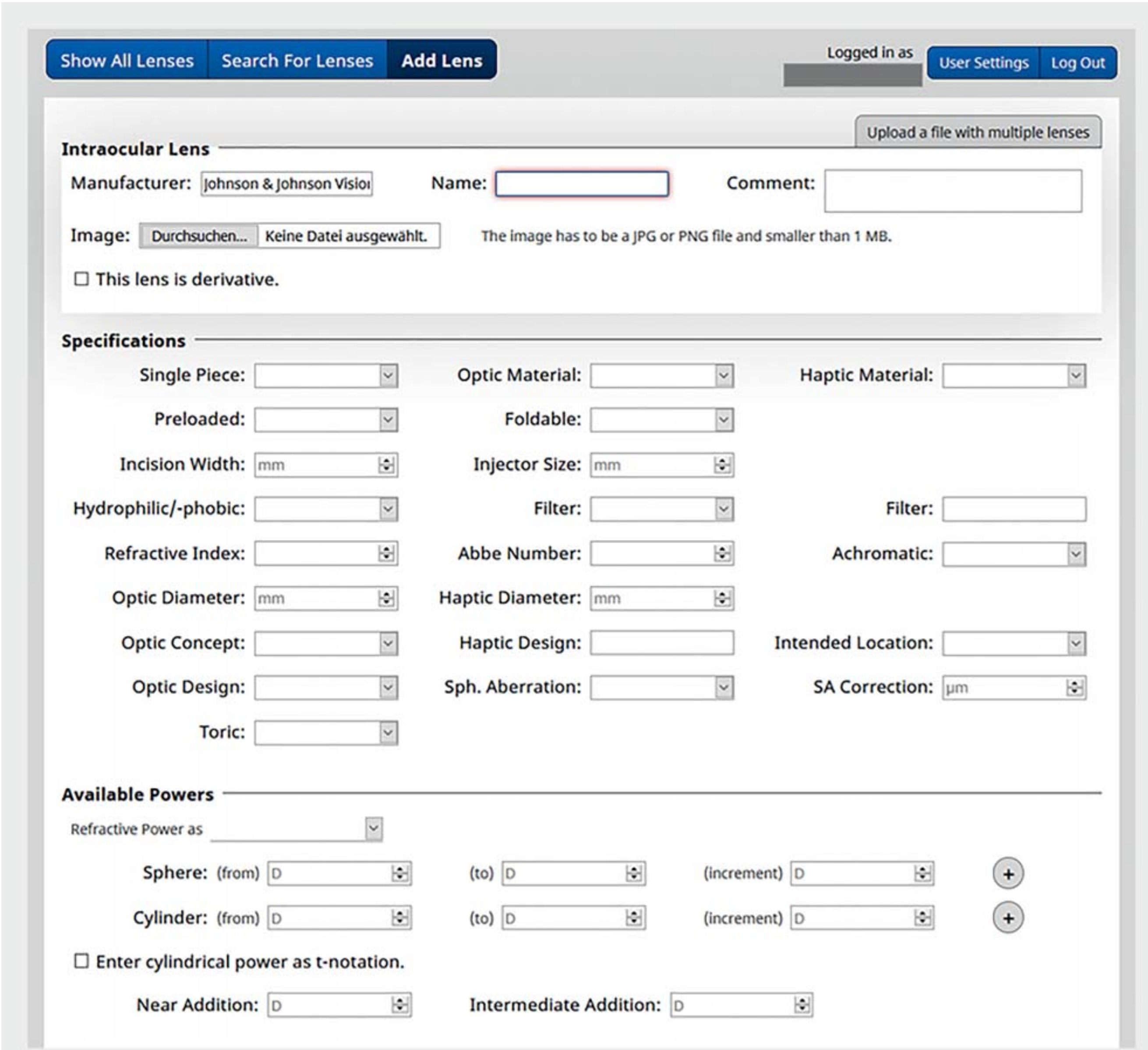
1. Registered IOL manufacturers and distributors can add and manage their IOLs and their parameters. The technical data of the artificial lenses are entered by an authorized employee of the respective manufacturers via password-protected access. Such parameters include optics and haptic material, available lens powers, optics concept (monofocal, multifocal, EDOF, toric), aberration correction, filters, and nominal IOL constants. (▸ **Fig. 9**). For data entry, either a Microsoft Excel file provided by IOLCon can be used or data for a specific IOL can be added manually to the database.
2. Registered ophthalmic surgeons or clinics can upload their relevant biometry and post-OP surgical data by using an XLS file. After a validity check, the uploaded data will be used for calculating globally optimized constants (based on community data) as well as for providing the surgeon with their respective individually optimized constant. All constants are available via an open data exchange format (XML) for easy implementation in biometry devices.

For optimizing constants, postsurgical data should preferably be retrieved 2–6 months post-cataract surgery. For constant optimization, especially for EDOF IOLs (but also for multifocal lenses), it is important that the visual acuity will be determined by using the "defocus curve" assessment technique, so that it is ensured that distance visual acuity is used for optimizing the constant.

A reliable subjective refraction under standardized and ISO compliant conditions at a measuring distance between 4 and 6 meters is needed, and the measuring distance should also be included in the template. Information regarding the refraction lane and the achieved visual acuity are already (optionally) included in IOLCon's data upload. Especially in case of larger deviations regarding the refraction lane, the refraction can be transformed to a target mark (e.g., 6 m) before optimizing the constant. For example, when converting data retrieved with a refraction lane of 4 to 6 m, the refraction is shifted by 1/12 D in the direction of myopia. When a "fictitious" measuring distance of infinity is used, a refraction offset of 1/6 D in the direction of hyperopia is taken into account. Unfortunately, this additional information was not collected for all data sets. It should also be mentioned which biometer and, in some cases, which keratometer index has been used. The quality of the optimized constants is shown by the quartile of the lens constants and the number of underlying data records are displayed to the user via a tooltip (▸ **Fig. 3** and **4**).

Summary

In cataract surgery, the selection of a suitable IOL power is crucial for optimal postoperative refraction. This can be improved by continuously optimizing IOL constants for corresponding IOLs and patient groups. By implementing IOLCon, a noncommercial, publicly available, independent platform for IOL specifications and formula constants has been provided to ophthalmic surgeons worldwide free of charge [7]. The design and implementation of the database ensures that it will also meet the future demands of ongoing developing ophthalmo-surgery.



▶ **Fig. 9** Web-based template for uploading IOL details by manufacturers/distributors.

Since its launch, IOLCon has established itself as a contemporary platform for the characteristics of IOLs and the optimization of the corresponding IOL constants. The database has grown steadily: As of January 2021, IOLCon offers data on approximately 486 IOL models from 29 manufacturers with almost 21 000 clinical results and optimizations for 120 IOL models. Biometry device manufacturers are already implementing IOLCon's open XML interface to integrate IOLCon with their devices to offer a direct download option [8]. Also, IOL manufacturers take advantage of IOLCon to present their most up-to-date lens characteristics to ophthalmic surgeons to further improve refractive results in cataract surgery [9].

IOLCon offers much more than a simple static table: it is a global, interactive, current and modern internet platform that provides ophthalmic surgeons with documentation of all IOL characteristics and IOL constants. It is also constantly updated, enabling timely and standardized publication and distribution of optimized IOL constants for the benefit of surgeons and patients.

Conflict of Interest

The authors declare that they have no conflict of interest.

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