Developments in cataract surgery: past, present and future

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Three millennia of lens surgery

History of cataract surgery goes back to antiquity. Four periods can be distinguished, which correspond to the main techniques: couching, extracapsular extraction, intracapsular extraction and cataract removal with IOL implantation.

The first technique consists of posterior displacement or luxation of the opacified lens using a needle to push it back towards the vitreous cavity so as to free the pupil area and enable the patient to recover a certain amount of vision, which will nonetheless be blurred without corrective lenses.

The oldest description of the cataract operation by couching can be found in the Susruta Asmita Sanskrit manuscript, written approximately in the 2nd century A.D. by Nagarjuna [1].

Another mention of what could be a cataract operation figures in the Bible, in the Book of Tobit (around 600 B.C.). Following instructions from the archangel Raphaël, Tobias applies the gall of a fish to his father’s blind eyes, «He applied the remedy which irritated his eyes. And he rubbed the corner of his eyes with both hands. Then he saw his son, threw his arms around his neck and wept as he said «I can see you, my son, light of my eyes» (Tobit 11 12-14). This description can be considered a self-induced cataract couching through vigorous rubbing, which overcome the resistance of a weak zonula (a frequent phenomenon in cases of mature cataracts), making the crystalline lens luxate into the vitreous cavity, thus liberating the visual axis [2].

Couching and its more or less deliberate variations continued without any fundamental changes throughout the first millennium of our era and for part of the second millennium. In the 16th century it was considered the favourite procedure for cataract surgery, according to the first modern textbook of ophthalmology, Augendienst by Georg Bartisch ; and in the mid 19th century, it actually reappeared again as an alternative new procedure [3].
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The modern era: cataract extraction

The next major stage was characterized by transition from couching to extraction of the cataract. Extracapsular extraction (so called because one extracts the lens contents, leaving the capsule in the eye) represents the first modern approach. To achieve this change of approach it was necessary to admit that a cataract was not a «condensed humour» in the pupil (as was the Galenic idea) but a solid body (which could therefore be removed physically). The first successful extractions are attributed to Jacques Daviel, a surgeon working in Paris about the middle of the 18th century (1748). Some similar procedures had been described previously however, specifically by the Arab surgeon Ammar Ibn Ali al-Mansili, who reported around 1000 A.D. a technique aspirating the lens through a cannula [4].

In fact Daviel’s technique derived from conversion of what was considered at the time to be one of the worst complications of couching, luxation of the crystalline lens towards the anterior chamber. Daviel resolved this complication by making a wide incision along the lower limbus and using external pressure to bring out the lens material. Soon after (1753), Samuel Sharp used the same idea in London, using pressure with the thumb without having first punctured the capsule of the crystalline lens. This was the precursor of the intracapsular cataract extraction «in toto», popularized a century later by Colonel Smith in India.

When Ignacio Barraquer invented his erysiphake in 1917, intracapsular extraction was quickly adopted as the preferred method. The instrument, a suction cup, was used to seize the crystalline lens and extract it with the wide pneumatic motorized cup, without breaking the capsule or disturbing the vitreous humour (fig. 1a, 1b and 1c).
Phacoemulsification avoided a number of complications inherent to previous procedures and brought about a further change of concepts, which prevailed in cataract surgery for a good part of the 20th century.

In 1957, the introduction of enzymatic zonulolysis by Joaquín Barraquer [5], made intracapsular extraction both easier and safer. Indeed, using an injection of alphachymotrypsine (a pancreatic enzyme, similar to the bile used by Tobias), produced selective lysis of the zonule. (*fig. 2a, 2b and 2c*).
Progress of cataract management could not be limited to improve the extraction maneuvers; functional rehabilitation of the aphakic patient also had to be improved. This led to the development of intraocular lenses and consequently a further historic turning point, with the return of extracapsular techniques, although using microsurgery.

**The century of intraocular lenses**

The idea of replacing the cataractous lens with an artificial «prosthetic» lens was contemplated already at the end of the 18th century by Tadini. According to the story told by Giacomo Casanova in his memoirs, he met Tadini during his trip to Warsaw in 1764-65.

During a heated discussion with a colleague, the Italian eye doctor brought out a box full of small lenses of the shape of a crystalline lens «to be placed under the cornea to replace the crystalline lens». When asked to perform a demonstration before the assembled faculty, Tadini attacked his adversary in the street and had to escape.

A few years later (1795), this idea was apparently put into practice by Johannes v. Casaamata, a Venetian eye doctor at Court of Dresden. The experiment failed because the glass lens fell back into the fundus of the eye immediately after having been inserted in the eye [6].

Another 150 years went by until Harold Ridley took up Tadini and Casaamata’s idea in 1949, after observing amongst RAF pilots a surprising tolerance to fragments of Plexiglas from the cockpit. Despite the fact that they were relatively lightweight compared to glass, Ridley’s first intraocular lenses (made from polymethylmethacrylate imitating the form of a crystalline lens and placed in the
posterior chamber) also tended to fall to the back of the eye or to luxate towards the anterior chamber (fig. 3a and 3b).
The development of intraocular lenses still had a long way to go, being placed firstly in the anterior chamber, supported in the iridocorneal angle, later being supported on the iris (pupillary lenses). It was only at the end of the seventies that the original anatomic location of the crystalline lens in the posterior chamber was readopted. The developments made and their current success were the consequence of a three-fold progress:

- Technological progress in terms of materials and methods for manufacturing and sterilizing lenses,
- Surgical progress with the development of micro-surgery, new methods of extracapsular extraction of the crystalline lens and viscosurgery [7].
- Physiological progress, with better understanding of the physiology of the eye, particularly of the corneal endothelium.

The triumph of technology has been one of the major features of the 20th century. Ocular microsurgery has for decades been on the crest of this wave (fig. 4). However we should keep in mind that technology also generated some of the darkest moments in the history of the past century. Even in the privileged environment of our humanitarian profession, technological progress has not been achieved without some memorable hitches. The probable peak in modern cataract surgery (development of intraocular lenses) has not been achieved without paying the price: the so-called «50 year epidemic of pseudophakic corneal edema» is one of the worst examples of iatrogeny in the history of ophthalmology and is still today one of the main indications for corneal transplants [8].
The current situation

In spite of amazing technical progress, cataracts remain the leading cause of blindness in the world, affecting almost half (45%) of the 40 to 45 million blind people worldwide according to the WHO, this number increases to 180 million when people with «visual deficiency» are included [9, 10].

Evidently, cataracts pertain to the 80% of cases of blindness that are considered avoidable and, in developed countries, they are no longer a major cause of irreversible blindness. Nowadays, for example, cataracts are considered to be the principal pathology in not much more than 2% of the affiliates of ONCE (Spanish National Organization for the blind [11]). In spite of this, demographic growth and increase in life expectancy, growing more rapidly than the availability of modern surgical treatment in vast areas of the world, will cause cataracts to contribute considerably to the increase of the total number of blind people in the world, the number of whom is estimated to reach 100 million by about 2020 if adequate resources are not mobilized urgently and if the necessary efforts are not made to change this trend.

Moreover, to date there are no preventive measures or medical treatments available which are able to avoid or delay the appearance of the most commonly seen cataracts - those linked to age. In developed countries, cataracts remain one of the main causes of visual loss in adults over the age of 50, and particularly after the age of 70. Although these people do receive very safe and efficient surgical treatment, they represent a burden for any healthcare system.

For example, in the wake of the generalized use of intraocular lenses, this kind of surgery was very nearly a victim of its own success: in the United States in the eighties it became the most frequent surgery undergone by people aged 65 (not only in ophthalmology but considering the total of all of medical specialities), endangering the economy of a system as solid as Medicare.

Maybe due to saturation, the number of operations stabilized from 1987, and a certain reduction in the number was witnessed from 1993 [12].
In our sector, these trends have been amortized to a certain extent by a slower growth rate in implantations of intraocular lenses, which did not exceed 50% of the total of operations until 1990 [13].

Latest trends are tending towards surgery using micro-incisions, becoming increasingly smaller. From the traditional incision (fig. 5a) measuring 8 to 10 millimetres for intracapsular or extracapsular with nucleus extraction surgery, the size decreased to incisions of 5 to 6 mm for manual fragmentation techniques and then to 3 to 4 mm using cataract aspiration techniques with the insertion of flexible IOL. With the arrival of injectable lenses the size went down to 2.8 mm (fig. 5b), and lately multiple incision techniques, scarcely larger than 1.5 mm have been proposed. Extraction of the lens content, using incision techniques of these sizes, has been made possible by means of the use of energies capable of breaking up the mass of the cataract to the point at which they can be aspirated using fine cannulae (aperture <1 mm), with increasingly sophisticated motorized irrigation/aspiration systems. The most widely used type of energy is ultrasound: the Charles Kelman’s phacoemulsification (fig. 5c).
In any case, alternative technologies, such as laser (although, so far, the latter has not been found as efficient as had been hoped) and others, such as the Aqualase system (pressurized water jet) are being experimented.

The new millennium: prospects and challenges

Cataract surgery is currently one of the most widely used medical procedures, and has the highest success rate. This is due to the fact that it is improving the quality of life in an increasingly large sector of our society. It allows to recuperate the visual function, quickly and painlessly, at an age at which it had previously been normal to lose certain faculties. Whereas the resolution of the normal crystalline lens is around 50 pairs of lines per mm (pl/mm), transmission declines gradually with age, down to only 30% at the age of 70, with «normal» nuclear sclerosis (knowing that it is reduced still further when a cataract forms). On the other hand, intraocular lenses reach a resolution level of 300 pl/mm, with a spectrum transmission of over 99% (with ultraviolet filter). This explains why many patients say that their post-operative vision is «better than ever» [14].

Recently, lenses with a yellow filter have been available, intended to limit the transmission of the blue component, which is the most highly energetic of the visible spectrum and which is thought to be linked to oxidative stress and the aging process of the retina. The best definition with current intraocular lenses is obtained, however, by giving up on certain other characteristics of the natural crystalline lens, particularly its flexibility, which is the basis for accommodation.
We can consider ourselves satisfied only when we are capable of recuperating, not only the static optical power of the crystalline lens, but also its dynamic or accommodative function, that enables us to focus at every distance.

Various strategies have been suggested to achieve this and no longer depend on spectacles for near vision. A first method consists of deliberately leaving one of the two eyes with some residual myopia (monovision method), which will enable a larger amplitude of distances.

There do currently exist multi-focal intraocular lenses that simultaneously generate images focused near and far. This requires a certain degree of cerebral ability from the user to select the image that is right in each situation. This method has also caused secondary effects such as loss of contrast and the perception of halos around luminous points.

«Accommodative» lenses have also started being offered, which move with the contraction of the ciliary muscle, gaining dioptic power, however these are complex mechanisms that have currently only reached a limited degree of accommodation. Finally, the return of physiological, active and constantly variable accommodation would involve re-formation of the crystalline lens, by filling the capsular bag with a transparent, bio-compatible, flexible substance, with the adequate refractive index.

The idea of rebuilding the crystalline lens by filling it with an appropriate substance goes back at least to Julius Kessler (1959). At our Institute, initial experiments in this field date from 1981 [15], and in 1987 the group led by Jean-Marie Parel in Miami demonstrated on primates the viability to recover accommodation by means of replacement of the lens material by a transparent gel (fig. 6) [16].

Various laboratories throughout the world are currently working on a project named Phaco-Ersatz
(substitution of the crystalline lens), which is based on four main sources:

- Surgical techniques, with which a great deal of progress has been made (fig. 7a, 7b, 7c, 7d and 7e).
- The chemistry of the creation of an appropriate gel, which is making progress.
- Biology, based on the prevention of capsular opacity, which is starting to produce encouraging results.
- Optical physiology (for example to find out the amount of gel to be injected), which still requires major research efforts.

The possibility of re-establishing accommodation would not merely be a progress in terms of functional quality (and consequently quality of life), offered to patients suffering from cataract.
It would also open up a new surgical field: that of the correction of presbyopia, which currently affects about 1.5 billion people worldwide; a figure that is constantly increasing.
In spite of the evident importance of these prospects, we should not forget the worldwide problem of cataract in developing countries. It is only at the price of an effort in terms of solidarity requiring participation by our profession in the design and implementation of strategies for detecting and treating cataracts, and particularly the training of local surgeons in modern techniques, that we will ensure that this pathology ceases to be the leading cause of blindness in the world.

This will be our first challenge for the new millennium.

References