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Painted Spectacles: Evidence of the Mughal Paintings for the Correction of Vision

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Painted Spectacles: Evidence of the Mughal Paintings for the Correction of Vision

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Abstract

This interdisciplinary study of Ophthalmology in India during the pre-modern times highlights the evidence of spectacles depicted in a few Mughal paintings. The study also demonstrates that there was a very rich history of optics and refraction in the medieval Islamic world. The theories of optics and refraction did not possibly make similar strides in the subcontinent. We have highlighted particularly the immense contribution of Ibn al Hytham, an eleven century polymath, to the theories of optics and refraction without which the lens for the spectacles cannot be manufactured. Historically speaking, the earliest spectacles were manufactured in Italy (13th century) from where these rapidly spread to other parts of Europe. The advent of European merchants in India from the 16th century onwards resulted in the familiarity with spectacles, at least in the court and elite circles. The paper also discusses the possible benefit of the use of spectacles for correcting aphakia, a refractive condition arising out of cataract surgery done in the subcontinent in the traditional couching/intracapsular/extracapsular method, modelled mostly on the celebrated medical treatise, The Sustrutasamhita.

Preliminaries

Recent decades have witnessed the flowering of the history of medicines as a major sub-discipline within History, strongly substantiating thereby the applicability of inter-disciplinary studies in History. This is an emergent sub-speciality of relatively recent times within the field of South Asian history, though its

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study is well established in the curricular agenda of the institutes of higher studies in advanced countries, mostly in the First World. In South Asian context, studies in medical history relate predominantly to the situations in the nineteenth and twentieth centuries, highlighting the impacts of the introduction of Western medical knowledge and practices during the colonial period on the 'traditional' medicines. The other salient feature of this study is the attempt to recover the indigenous and pre-modern knowledge, system and practice of medicine largely by relying upon the Ayurvedic texts. There is no doubt whatsoever on the celebrated richness of the medical knowledge in the sustained tradition of Ayurveda. The historian's understanding of the Ayurveda mostly stems from the readings of two premier texts, the *Charakasamhita* and the *Susrutasamhita* and a voluminous commentary-literature on these two medical treatises. The pre-modern knowledge of various diseases and their treatments figures in these treatises. A critical appreciation of these ideas, and not mere blind glorification of ancient texts, is the watchword for the historian of Indian medicine who has little compulsion to claim that most of the modern medical scientific knowledge and practices were anticipated in the Ayurvedic treatises of hoary antiquity. The expertise in this field largely belongs to the Sanskrit and Ayurvedic scholars (e.g the mammoth work of Meulenbeld on the Indian Medical Texts and his massive Bibliography on this subject available in electronic resources)[1]. It has also been pointed out that the earliest possible literary references to diseases and healing processes possibly go back to the *Atharvaveda*, the hymns known as *paushtikani sutrani*. As is expected, many textual and Ayurvedic scholars have approached such traditional medical treatises with a distinct orientation to showing that many modern diagnostic and preventive methods were anticipated in these pre-modern texts. The other significant enquiry into this field is of relatively recent origin. The postcolonial and postmodern critique of the universality and the dominance of the Enlightenment ideas has of late tried to recover the local genius that had been displaced by the impact of the advanced European/Western medical science, diagnostic and therapeutic methods. Sustained efforts have been launched to appreciate the herbal and botanical knowledge among the traditional practitioners of medicine in the seventeenth, eighteenth and early nineteenth centuries, noted and recorded by European/Western travelers, ethnographers and administrators. The other thrust area has been that of the interconnection between the British Raj and Sciences, the making of 'Colonial Sciences', the creation of institutions for Science and Technology Education and the study of the management of epidemics under the British Raj. The contributions by Deepak Kumar and David Arnold, deserve special mention in this context[2].

It needs to be emphasized that albeit a growing body of scholarly literature on the history of epidemics like cholera, small pox, malaria and plague in India in the nineteenth and twentieth century, there exists a virtual blank regarding the understanding of other disease of similar proportion and fallout. This is the area of Ophthalmic diseases causing blindness, like cataract and glaucoma, that affect a huge multitude of Indians. While understanding of the virulence of Ophthalmic diseases in India and their diagnostic and therapeutic methods have largely escaped the attention of historians of medical sciences of modern times, not much sustained enquiry into the subject is also available by a systematic probing into the traditional medical treatises. This is a major desideratum in the study of the history of medicine in India; the present research project aims to address this issue.

II

The present research project on *Drishti* (literally vision) is planned to undertake a thorough and elaborate study of Ophthalmic diseases and their treatments in pre-modern India with a thrust on the early period of Indian history (up to c. AD 1300). The project intends to initially study four early Indian treatises of enormous significance: the two *samhitas* of Charaka and Susruta, the *Ashtangahridayasamhita*[3] (of c. seventh century) and the eastern Indian medical treatise, *Sabdachandrika* by

Chakrapanidatta[4] (c. twelfth century). The recent findings of Vijaya Deshpande enlightens us on the transmission of early Indian Ophthalmological knowledge to China through Central Asia during the heydays of India's commercial and cultural transactions with China. Many Indian ideas of Ophthalmolgy are found to have entered the world of Chinese medicine; Indian medical treatises discussing Ophthalmic diseases were translated into Chinese[5]. The long tradition of understanding the eye and its diseases continues in India during the period subsequent to the thirteenth century. It will indeed be a valid enquiry to examine how and to what extent the Ayurvedic ideas of eye diseases interacted with Yunnani medicine from West Asia in the post-thirteenth century period. That the traditional Indian medical system interacted with the newly emergent Western medical approaches to Ophthalmology is well illustrated by the keen interests of Serfoji II (1798-1832), the last Maratha ruler at Tanjore(Tamilnadu), in European Ophthalmology. He established a hospital (*arogyasala*), named Dhanvantari Mahal within his palace complex. One of the most spectacular documents therein is the case sheet of 63 patients with various types of ophthalmic diseases which were treated in that hospital. The document also contains many paintings of the eye, before and after its treatment.[6] The history of the pre-modern Indian Ophthalmology should ideally be extended up to the end of eighteenth century since when modern Western medical sciences gained upper hand in India.

During our searches on this line of enquiry, we came across, by sheer chance, a few paintings of the Mughal times, showing the use of spectacles. None of these paintings are unpublished and all are easily available in well-known published catalogues and historical works on the Mughal painting. Most of our specimens depict the master artist (the *ustad* and not his apprentice or *shagird*) at work wearing a pair of spectacles. The source material here is quite different from what we have discussed above. The Mughal miniatures have captured the attention and enquiry of many art-historians over a sustained period of time, resulting in a voluminous literature on the Mughal paintings. The style, aesthetics, form and content of the Mughal paintings would not be our principal focus here as these issues primarily address the problems of art history. A survey of the Mughal paintings also demonstrates that these have been profitably utilized by historians as visual records of the-then technologies and also of socio-economic conditions. The foundation and expansion of the Mughal rule in India coincides with the growing presence of the powers and trading companies from the North Atlantic – viz. the Portuguese Estado da India and the three East India Companies of the Dutch, the French and the English. The interactions of the Mughals with these Europeans—largely through the Mughal court—paved the way for cultural transactions and also occasionally for technological transfers. One of the best documentations regarding this comes in the form of the Mughal paintings. This is particularly visible, for instance, in the depictions of the globe, the map and sand-dial, in the Mughal paintings; these objects were imported from Europe, not indigenous to India, and were regularly gifted to the Mughal emperors as exotic, curious and prestige goods by representatives of the European companies. It needs to be further stressed that the Mughal miniatures were products of the court, created by outstanding artists for their royal patrons in the Mughal ateliers (*karkhanas,*). These miniatures were specifically meant for the private viewing of the Mughal ruler and his very close circle of court elites. Spectacles were the tools or instruments for corrections of problematic vision, whether it was myopia or presbyopia or hypermetropia, by using manufactured and appropriate lenses made of glass. There is no indication whatsoever that spectacles became known in the subcontinent before 16^{th} century CE; moreover, there is also little to prove that there was an indigenous tradition of the science and technology required for the manufacturing of spectacles in the subcontinent. On the other hand, there is incontrovertible evidence of the advent and use of spectacles in Italy as early as the fourteenth century CE. The classic case in point is Petrarch's (1304-70 CE) lamentations on losing his sight and the resultant inability to read and write when he was sixty years of age. In his Letters to Posterity Petrarch also spoke of his taking recourse to spectacles for the correction of his failing vision and he also recorded the relief that the use of spectacles had brought. There are grounds to believe that the advent of spectacles had taken place perhaps at least by the middle of the thirteenth century; this is a point to which we shall come back later.

In the absence of any known antecedents of the use and manufacture of spectacles, nor of any indigenous theory on the glasses or lens for correction of refractive errors, the present study has to take into account the following related matters:

a) a general understanding of the theory and use of lenses for vision correction, especially prior to the sixteenth century.

b) The centrality of the theories of optics in the use of lenses for vision correction.

c) Integral to b) is the gradual transformation of the theories of optics from sight to light: a broad survey of the concepts of Euclid, Ptolemy and Ibn al Haytham is crucial; al Haytham's theory of light and optics is of signal importance, deeply influencing the theories of Roger Bacon, Descartes, Johannes Kepler and Christian Hyugens.

d) The study of the Mughal paintings depicting the use of spectacles—the principal point of attraction of this present essay.

e) In short, before embarking upon the analyses of the Mughal paintings, certain theoretical issues on optics, light and lenses need to be discussed here, albeit briefly. We have drawn heavily upon the existing literature on the history of the scientific explanations of light and optics for this section.

III

Physical Optics

What is light? This question has been the subject of vigorous debates for centuries. On the one hand, stood the proponents of the wave theory, originally stated by Christian Huygens and amplified by Young and Maxwell. Opposed to this school were those who championed the corpuscular theory, originated by Newton and supported by Planck. Ultimately, however, both theories are necessary to account for all of the phenomena associated with light. The science of quantum mechanics that evolved from Planck's quantum theory successfully addresses the dual nature of light by comprehending both the particle and wave aspects of light.

The description of optical phenomena is currently divided into the areas of physical optics, geometrical optics, and quantum optics. Physical optics describes those phenomena which are most readily understood in terms of light's wave properties. Geometrical optics conceives of light as rays and deals with the imaging of lenses and mirrors. Quantum optics is concerned with light and matter and, as the name suggests, considers light as having both wave and particle (photon) characteristics.

In brief, light behaves like a wave as it passes through air, a vacuum, or transparent materials. Light exhibits some characteristics of particles (photon) when it is being generated or absorbed. The ray model is a simplified method for describing the propagation of light. Although it ignores the effect of diffraction and other physical optics phenomena, it provides a powerful method for calculations involving lenses and images.

Since our primary interest lies in the propagation of light through media, including transparent ocular tissues, the wave and ray descriptions of light hold a crucial clue to our study, with only occasional references to its photon characteristics[7].

IV

Pre-modern Theories of Light and Optics

A broad survey of the concepts and formulations in this subject is a pre-requisite in the understanding of the use of lens and spectacles in South Asian since 16th century CE. Euclid's articulation of the visual-ray theory (c. 300BCE) marks the beginning of mathematical optics by formulating that the discrete lines of visual flux (subtle optical fire) in rectilinear bundles, emitting from the eye, formed a cone whose vertex defined the centre of the sight and its base represented the visual field. Within this field whatever is touched by the flux becomes visible with the resultant visual information being conveyed back through the flux-line to the centre of sight. Four and a half centuries down the line, Ptolemy's elaboration of this theory (c. 150 CE) demonstrates the structure of optical analysis acquiring a conical form. Its tripartite divisions are: a) optics (unimpeded radiation), ii) catoptrics (fully broken or reflected radiation) and c) dioptrics (partially broken or refracted radiation).

In spite of the apparent similarities between ray theories of the ancient and the modern times there is one crucial difference. Ancient theory sought to explain sight, while the modern one explained light. One major presumption in the formulation of the Euclidean-Ptolemaic ray-theory is to establish a physical sense-link between the viewpoint and the external objects, thus advocating a simple mathematically determined spatial relationship between the viewpoint and the point viewed. The next step is to explain the visual properties like shapes and sizes in terms of angles and ray lengths. In short, the Euclidean-Ptolemaic ray represented a line of sight rather than a path of light. Thus light is all but ignored in this ancient visual ray-theory which treats light as a mere pre-condition for, but not an actual object of, sight. But actually the two can be united in a single inward reach of the visual information, somehow physically radiating from the external objects to the eye.[8]

This unification is precisely the achievement of Ibn al Haytham, a polymath of the 10th-11th century CE. Born in Baghdad in 985 CE, he later moved to al Kahira (Old Cairo) in Misr or Egypt under the Fatimid Caliphate; he died close to the same city in 1040 CE. Celebrated for his as many as 96 scientific titles, according to pre-modern bibliographers, al Haytham left his indelible mark in history particularly for his 14 titles on optics and 23 on astronomy. He further substantially contributed to the history of mathematics, statics, hydrostatics—in short, on all mathematical sciences of his times, except algebra. His outstanding work was, of course, the multi-volume *Kitab al Manazir* (*The Book of Optics*, especially its Books 2-4)[9].

The crux of his argument on the theory light and optics is as follows: he built on the notion that every point of light or luminous colour on a visible surface replicates itself continuously and omnidirectionally as a formal effect through the transparent media. It results in a sphere of propagation with each radius a sort of trajectory for point-forms of light and illuminated colour. As and when such point-forms reach the eye, physical impressions occur on the surface of the crystalline lens, paving the way for visual sensation. However, only those point-forms, which strike orthogonally, result in an effective impression. Thus on the lens occurs a perfect point-to-point correspondence between a visible surface and its physical/visual impression. Al Haytham thus created a cone of visibility, mathematically identical with, but physically opposite to, the Euclidean-Ptolemaic visual cone. The crucial point of the theoretical departure of al Haytham from his predecessors (most importantly Euclid and Ptolemy), in the understanding of vision and optics, was the irreversible shift from the centrality of sight to the centrality of light[10].

The signal importance of this treatise resulted in the Latin translation of the *Kitab al Manazir* in c.1200 CE, under the title *De Aspectibus* which soon became an authoritative text among scholastic circles and exerted discernible influence on Roger Bacon (*Perspectiva*, 1275) and John Peckham (*Perspectiva Communis*, 1280), thus forming the very core of the Perspectivist optical tradition[11]. It also led to the growing acquaintance with the name of Alhazen or Alhacen in the Western intellectual world. What were added to al Haytham/Alhazen/Alhacen's contribution were the Perspectivists' attempts to explain the action of light in quasi-mechanistic terms by which the radiation of light was treated virtually, but not literally, in terms of physical projection through space. The recasting of light radiation in mechanistic terms in the 17th century goes to the credit of Kepler (*Ad Vitellionem Paralipomena*: Emmendation or Supplement to Witello: 1604), Descartes, Pierre de Fermat and Christian Huygens. Kepler reduced the eye to a mere camera within which the incoming colour images were radially projected via the crystalline lens onto the retinal screen. He also presented the definitive account of the projection of the pinhole images in the *camera obscura*[12].

Descartes propounded the physical theory of light in terms of mechanical impulses transmitted rectilineally and instantaneously through a continuous, unyielding aethereal medium. Fermat further advanced the theoretical formulation by establishing that light consists of literally minute particles hurtling radially through the space at an enormous speed. The final reformulation of the Cartesian account of light was offered by Christian Hyugens in terms of the longitudinal wave-fronts passing swiftly through a continuous, but highly elastic aethereal medium. Thus, by mid-17th century light was completely and literally transformed from a formal to a material effect, benefitting immensely from al Haytham's path-breaking shift of mathematical optics from sight to light in the eleventh century.

Catoptrics

Since Euclid's times, the equal-angles law of reflection was well known, which established that the point-image in a plain mirror was located at the intersection of the line joining the eye to the point of reflection and the perpendicular would drop from the object-point onto the mirror's surface (= cathetus of incidence). To this, further additions were made by Hero (of Alexandria, mid-first century CE) who demonstrated the necessity of the equal-angles law by proving that the shortest possible ray-couple would link the centre of sight to the point of reflection and the point of reflection to the object-point. Reflections must follow the minimum path followed by this ray-couple.

Ptolemy reached a level far higher than the formulations of Euclid and Hero, providing in his *Optis* the experimental verifications of the law of equal angles for plane as well as cylindrical, concave and convex mirrors. He made systematic investigations of the image-location in all three kinds of mirrors and precisely explained how the location and size of the image were distorted in carved mirrors and how to determine multiple image-locations in concave mirrors. Thus he laid down the blueprint of the subsequent studies of reflection. Al Haytham followed Ptolemy's lead and offered a similar analysis according to the types of mirror, its complexity ranging from plane to convex (subdivided into spherical, cylindrical and conical) to concave (equally subdivided). But as al Haytham had more sophistication of mathematical approach than Ptolemy, one discerns a greater specificity and complexity in his treatment of the subject. What is called by Fermat as "Alhazen's problem", therein one finds a far higher level of geometrical knowledge, especially the conic sections. Given a centre of sight and a point on a visible object, he was able to find the point of reflection on a convex or concave circular mirror. In fact, al Haytham's study of reflection remained unsurpassed till the application of algebric techniques in the 17th century CE.

Dioptrics

The first systematic study of refraction was done by Ptolemy in his *Optica*. The centre piece of his study was an experimential effort to determine the index of refraction from air to water (as well as from air to glass, and water to glass). Ptolemy's apparatus consisted of a hollow semi-cylinder glass and a circular plaque divided into quarters by two diameter lines and marked off in 1 degree subdivisions along its circumference. The semi-cylinder would be filled with water; Ptolemy placed the plaque upright in it, so that one of its diameter-lines coincided with the water surface, while the other cut it along the normal. A small marker was affixed to the plaque's centre. Ptolemy attached a further 10 degrees from the normal along the section of the circumference lying above the water. Along this line connected by two markers, Ptolemy adjusted another marker on the circumference below the water until all three markers lined up. The arc between the normal and the marker below the water's surface represented the angle of refraction. His track was followed for nearly a thousand years with the only exception of Ibn Saleh (10th century CE) who adduced the correct relationship of sines. On this conceptual premise he proved that the surface of refraction, that would focus parallel rays to a single point (the anclasitc surface), would be hyperbolic. However, his discovery remained unnoticed.

The invention of the telescope (1608) generated a sustained interest in lenses. The study of refraction received a new vigour at the turn of 16/17th centuries. Kepler made the great contribution to the gradual fading out of the traditional understanding of refraction. Snel and Descartes (also Harriot) are credited with the discovery of the sine law. The formulations are available in the *Dioptrique* (1637), and the derivations therein are based on two assumptions: 1) the speed of light in any transparent medium will be directly proportional to the medium's optical density; 2) when light passes obliquely through the interface between the media of different optical densities, its motion along the horizontal vector is conserved. The resulting proof confirmed that sine laws aroused such critical reaction. Fermat adduced his own counterproof, perfected by 1662, in just such reaction. He assumed the speed of the passage for light through any given medium inversely, not directly proportional to medium's optical density. His further assumption was that any light particle passing through the interface between the media of different optical densities will follow the path that is most temporally, not spatially, economical. He proved that such a path is the one dictated by the sine law[13].

V

Ibn al Haytham's Impacts

Coming back to al Haytham once again, we would like to underline here his careful study of the structure of the human eye; he also successfully analyzed the stereoscopic properties of the human eye. As we have already stated, he transformed the Euclidean theory of vision from sight to light; he further added that the rays from the perceived object led to the composition of a form which represented an object's visible features. These visible features, according to him, entered through the pupil (which acted as a lens) and proceeded on to the brain wherein the faculty of sense completed the process of imaging. In al Haytham's model of vision, therefore, the eye is involved as an optical system in which psychology too played a role. He argued that the pre-recorded images of the object viewed also came into play by the psyche. Ibn al Haytham broke new grounds because he successfully combined hypotheses and ideas with repeated observations by applying the-then instruments and apparatuses like prisms and gratings. He is known to have availed of the local skills in Cairo in making the glass prisms and hemispheres; the mirrors he used for his experiments of reflection were made of steel. In this sense, he was atypical of the ethos of the scientific enterprise in medieval Islam that tended to depend excessively on the authority of the established axioms, whether of Greek or Ptolemaic origins[14]. A younger contemporary of al Haytham, Abu Ruh Mohammed bin Mansur al Jurjani brought out a treatise on Ophthalmology in 1087-88 CE. Written in the form of questions and answers, his work contains chapters on the diseases of the human eye visible to the naked eye, curable diseases of the eye, incurable diseases of the eye, measures to be taken during the early stages of eye problems, surgical treatment of the afflicted eye and simple and complex treatments of the eye-disorders. He seems to have borrowed from a treatise by Hunain ibn Ishaq to whom goes the credit of having drawn for the first time a detailed anatomical diagram of the human eye[15].

It is a bit strange that with all these landmark theoretical developments in the field of the vision, light, optics and mathematics achieved in medieval Islamic sciences, the actual manufacture of the earliest known spectacles took place in Italy. Ilardi suggests on the basis of textual and pictorial data that the earliest spectacles (*occhiali*) were reported from Italy in the late thirteenth century; these were convex lenses intended to correct presbyopia. He cites a sermon delivered by the Dominican Friar Giordano da Pisa (1255-1311 CE) on 23 February, 1306:

> It is not yet twenty years since there was found the art of making eye-glasses, which make for good vision… I saw the one who first discovered and practiced it…. I talked to him[16].

This, according to Ilardi, provides the clinching evidence for marking 1286 as the manufacture of the first eye glasses. Ilardi further cites an Ancient Chronicle of the Dominican Monastery of St. Catherine in Pisa:

> Eye-glasses having first been made by someone else, who was unwilling to share them, he (Alessandro Della Spina) made them and shared them with everyone with a cheerful and willing heart[17].

It was on this ground that Rosen credits an anonymous layman of Pisa with the manufacturing of the first spectacles in 1286 CE. Friar Alessandro della Spina of Pisa made the first public declaration about the manufacture of spectacles in Pisa; he actually saw them being made and ordered one for his own use. Crombie has cited Roger Bacon who in 1266-67 proposed that a convex lens held in front of the eyes could effectively cure long-sightedness[18]. The earliest use of spectacles in the thirteenth and fourteenth century had an intimate linkage with the clergy who in their advanced years needed an adequate instrument to help them read scriptures[19]. The First Dominican Cardinal, Hugh of St. Cher (born 1200- death, 19 March, 1263), figures in a painting by Tommas de Modena in 1352[20]. The painting was done in the Chapter House of San Nicholas Monastery, Traviso, in northern Italy. Dressed in a deep brown hat and a black gown (beneath which a white full sleeve attire is partially visible), the cardinal appears in this painting as engrossed in reading/writing in the Scriptorium with the help of a pair of riveted eyeglasses. He holds a pen-like writing instrument in his right hand. This is the earliest known pictorial depiction of the use of spectacles[21] (fig. 1). The second specimen shows a bearded apostle, in a purple dress, with long hair and in a seated posture holds a pair of lenses with his left hand to keep them steady on the eyes while he reads. The depiction comes from the details from the Death of the

Virgin by the Master of Helligenkreuz, datable to ca. 1400-1430 CE (fig.2). Here too the use of the riveted glasses is unmistakable. Apparently the heavy presbyopic lenses, required by clergies of relatively advanced age, fitted with riveted frames, could have become too heavy and probably tended to slide down the bridge of the nose. That is why the apostle is shown as holding the spectacles by fingers of his left hand, while in his right hand he reads a book with blue cover. The artist's depiction of holding the spectacles by fingers further heightens the visual effect of a thoughtful pose of the apostle, immersed in reading a book.

These two specimens of painted spectacles highlight its association with the elderly and scholarly clerics whose erudition seems to have been driven home by the depiction of their wearing reading glasses. It is also very likely that these were spectacles for the correction of presbyopic vision; this is further evident from the depictions of the spectacles located below the bridge of the nose. The delineation of spectacles of course points to the regular manufacturing of the same. A thriving glass industry is reported at Burano in Venice; the manufacture of spectacles was associated with a crystal workers' guild (1300 CE) which also made magnifying glasses. The proliferation of the manufacturing of eye glasses is perhaps indicated by the guild regulation in Venice governing the sale of eye glasses[22]. More or less around the same time, physicians in Italy began prescribing spectacles as a remedy for those suffering from presbyopia which could not be cured by the application of salve and lotion[23]. What is clear from the above discussion is that the technology of spectacles-manufacturing originated in Italy, while the scientific formulation of optics and image should go to the credit of Ibn al Hyatham.

Needham dated the earliest use of spectacles in China to the late fifteenth century when Ming sources first referred to *ai-tai* (eye glasses), which was possibly derived from Arabic *al uwainat* or Persian *ainak*. This implies the movements of the spectacles-manufacturing technology from Italy to China after fourteenth century[24]. Exactly when and how spectacles reached South

Asia is difficult to ascertain. There is no known evidence of the indigenous knowledge and use of spectacles in the subcontinent prior to the sixteenth century. P.K. Gode and I.G Khan have cogently argued for the growing use of spectacles both in the Deccan and the Mughal north India from the sixteenth century onwards, thanks to the contacts with the Portuguese. The *Vysasyogacharita* by Somanatha Kavi (c. 1520 CE), as Gode demonstrated, refers to a device *upalochanagolaka*. The term literally stands for round glasses which were substitutes of natural eyes (*upa-lochana*).[25] It therefore denotes eye glasses, made possibly of convex lenses. The most likely route of transfer of this technology was the gift-giving by the Portuguese to the Vijayanagara court in the Deccan. To this should be added the Jessuits' role in the growing exposure of this device to Indian rulers. Rudolf, for instance, is known to have used one such pair when he visited the emperor Akbar's court in 1580. It is, therefore, no wonder to come across the word *ainak* (glass) as a synonym of *chashma* (sight/vision) in the *Farhang-i-Jahangiri* by Jamaluddin Inju. This crucial evidence of the growing use of spectacles, at least in elite court circles, is made available to us by I.G. Khan whose excellent work on this subject has opened many new possibilities in this field of study[26]. It is however somewhat surprising that Khan did not delve into the visual representation of spectacles in the sixteenth and the seventeenth centuries paintings, mostly associated with the Mughal court. This is something we would like to present here.

VI

Painted Spectacles in the Mughal Miniatures

Our survey opens with a remarkable painting of a pre-eminent Saffavid painter, Mir Mossavir (gouache on paper 12x11.1 cm, now preserved in the Musee Guimet, fig. 3)[27]. Painted in a golden background with red bands (decorated with intricate floral motifs) at the top and the bottom, the scene depicts the celebrated painter wearing an elegant blue long *jama* with golden embroidered designs all over it; a bright yellow sash is also knotted at the waist. The painter also wears a cap with diagonally parallel designs. His advance age and senior position is clearly evident from the white beard he sports. Kneeling down the painter is depicted as engrossed in reading a long scroll. It is impossible to miss that Mir Mossavir is shown here reading the written words in the scrolled document with a pair of riveted spectacles placed definitely below the bridge of the nose and almost at the middle part of the nose. The position of the riveted spectacles, coupled with the tell-tale signs of the seniority of his age, strongly suggests that the spectacles were made of convex lenses, typically meant for a presbyope. The written words on the scrolled documents are decipherable and inform us that it was a formal petition by the artist himself seeking employment at the court of the Mughal emperor Humayun. The image of Mir Mossavir was painted by his son and apprentice Mir Sayyid 'Ali sometime between 1565 and 1570 CE.

This takes us to the second specimen which is dated in 1596 and now kept in the Bharat Kala Bhavan (figs. 4a and 4b)[28]. It is an unsigned painting, so the name of the artist remains unknown[29]. It shows once again a master artist at work, possibly inside the atelier. The master artist here is in the company of his apprentice. Both are seating on a richly embroidered carpet that spreads across the greater parts of a room with a half-open door. Several niches are visible on the wall mostly containing slender-necked vessels. In two niches can be seen books and a goblet. The impression is that of a comfortable and well appointed room where the master artist works. The artist is seated with his left leg in a kneel-down position, while the right knee is raised. On this raised right knee the master artist has placed a piece of paper. With the fingers of his left hand he holds this piece of paper; his fingers of the right hand hold a pen/brush that lightly rests on the paper on which the master artist has focused all his attention and concentration. Attired in a typical long *jama* with a sash knotted around his waist, the artist sports a moustache and wears a turban-like headgear. The artist intently looks at the piece of paper through a pair of riveted spectacles, made of round glasses, positioned almost to the middle of his nose. It is unmistakable that he is more than a middle-aged person and therefore requires a pair of convex lenses to overcome his presbyopia. In front of him in a kneel-down position sits his apprentice, certainly junior to him in age, and therefore not wearing a pair of spectacles. The apprentice like his master also wears a long *jama*, but its long sleeves are rolled up as he uses a pestle and mortar type of artefact in order to prepare the required paste of colour for the master's brush. Some portions of his pyjama like lower garments are also visible. Open books and pages on the carpet may suggest the written instruction of making the colour(s) to be applied for painting and/or calligraphy.

One of the Mughal master painters, Farrukh Beg made a painting of a Sufi saint in 1615[30] (figs. 5a and 5b). The Sufi saint is shown in a pensive mood, lost in thought and seated on a chair-like high wicker stool under a tree, the leaves of which have been depicted in a distinctly European style. He is obviously located in or close to a garden, as he is surrounded around his feet by a curled up dog, a lamb, a deer suckling its two cubs and a seated cat behind him. The Sufi saint wears a pair of covered slippers. His long gown-like garment, a long stick resting lightly between his palms clasped together and the leaves of the tree under which he sits – all are likely to have been influenced by European art-motifs and themes. The whole scene is placed within a courtyard which is surrounded by a low wall. In the background appears a low platform on which is seen a closed book with a red cover. On the closed book is kept a pair of riveted spectacles; another pair of similar looking riveted spectacles are visible beside the book. The scene conveys the sense of a Sufi saint lost in deep thought, probably as a result of his reading which is indicated by the book and the two pairs of spectacles. The artist perhaps also adds humour to the scene when he shows several expensive utensils and decanters in an elegant cupboard. A cat has slipped into the half-opened cupboard from where it has displaced a container of milk which flows out of the container. The cat is licking the enjoyable drink while the Sufi saint is completely lost in thought and unaware of the presence of a stealthy cat. What is significant here is the association of spectacles with an elderly Sufi saint who has been reading a book and immersed in his deep thoughts. In other words, the artist links the spectacles with advanced age, creative thought and erudition.

Now to the next painting by another great Mughal artist, Payag, This gouache on paper (measuring17x23 cm.) is now in the Chester Beaty Library, Dublin (fig.6). We are not primarily interested in the principal theme and content of the painting which is known as Officers under the Tree[31]. The piece is dated to 1650-55 CE. We would like to draw the attention of the reader/viewer to a border decoration within an oval frame on the left. There are actually three such border decorations, each within a oval frame; the three oval frames are joined by two figures of flying birds within two circles. The second/middle oval frame shows a senior person in a white turban, white long-sleeved *kamiz* and a striped *jobba*, reading a book with the help of a pair of spectacles held below the bridge of the nose. This is an interesting variation in the depiction of the spectacles. On two previous instances the painted spectacles are associated with master artists at work; in the third case the scene hints at spectacles being used for reading a book. Here we encounter an elderly person, whose identity is unknown, using a pair of spectacles actually for reading a book. The factors of old age and knowledge-gathering are once again used in combination with spectacles which, in this case too, are likely to assist a presbyope. The point of departure is the portrayal of the reader as a border decoration of a painting. It, therefore, may imply that the use of spectacles had become quite frequent and in fact, commonplace. That is why a bespectacled figure could be used a border decoration of a Mughal painting of mid-seventeenth century.

In c. 1640 CE the celebrated Mughal painter Bishun Das wonderfully captured a courtly scene showing Zafar Khan, the Mughal governor of Kashmir, and his brother (figs. 7a and 7b).[32] Azam Khan and his brother appear here in the company of assembled poets and scholars. The two brothers are seated in the typical kneel-down position and facing several poets, scholars and musicians. All personalities are dressed in beautifully coloured attires and turbans; the richly embroidered carpets further enhance the aesthetic appeal of the decorated hall. Through one open window of the hall are visible the outdoor scenic beauty of mountains and the lush green valley . We would like to specially point to the figure of the artist/ painter, kneeling down in front of and to the left of Azam Khan and his brother. That he is a senior artist will be unmistakably evident from his greying beard. Dressed in a bluish-grey long garment and a striped cap/turban atop his skull, he also wears a sash around his waist. The artist himself intently looks at the scholars, poets, and the two brothers, ready to visually capture the moment. That is why, he is shown ready and prepared with a piece of white paper and a pen/brush placed on his upraised one knee. A close look at the face of the artist clearly shows a pair of spectacles, once again held almost at the middle of his nose, implying thereby that the spectacles were probably made of convex lenses needed by an elderly presbyope.

So far, we have presented specimens of painted spectacles associated with reading, painting and calligraphy, in which elderly artists regularly engaged. In only two cases the images of spectacles had linkages with the act of reading a book, once again by men of advanced years. A remarkable exception to this general pattern comes in the form of the depiction of Jahangir's *jharokha*, painted by Nadir az Zaman (Abu'l Hasan), one of the most famous painters of the Mughal times (figs. 8a and 8b). This Gouache on paper (11.6x6.5 cm). is now in the Prince Sadruddin Aga Khan Collection and dated to c. 1620 CE[33]. It shows the figure of the emperor Jahangir in profile at the top of the background. Jahangir is visible through the *jharokha* window, obviously for letting the assembled courtiers have a ceremonial and auspicious sighting (*darshan*) of the emperor. This symbolic act of the emperor's *jharokha* is fraught with political significance which need not be elaborated here[34]. The Mughal fort dominates the background which also shows several other structures atop the fort made of red sandstone. Somewhat below is painted a white structure with flanking staircases on its both sides. On this structure and on the double staircases have flocked a number of Mughal court elites who obviously would take their respective turns to have a ceremonial glimpse of the emperor. The foreground presented two more groups of assembled courtiers and a thin strip of empty space neatly divides the two groups of onlookers. All are attired in very colourful and fine dresses; an elephant's frontal parts and a musician can also be spotted among the courtiers. In the front row of the assembled men on the right hand side, a court elite waits for getting a glimpse of the emperor. He wears a white turban, an orange wrapper over a white *jama*, and sports a fine moustache. He clearly looks up and at a distance, intent upon catching a glimpse of the emperor. What is striking is that the courtier wears a pair of riveted spectacles which rest almost on the middle part of his nose. He evidently is not a young person and this spectacles are typical of the one used by a presbyope. But the man here is neither reading nor writing; his use of eye glasses in this case is therefore likely to have been required for observing something at a distance: in this case the figure of the emperor. The logical question arises whether in this specific instance the pair of spectacles is made of convex or concave lenses. The latter is required by a myope and not a presbyope. If the eye-glasses here were indeed meant for correction of myopia, then we come across a pair of spectacles different from those used for long-sightedness. It is difficult to ascertain the exact nature of the glasses here. It is equally plausible that the artist depicted a pair of glasses even for non-reading purposes to highlight the elderly status of this court elite. It could well have been a statement of his status, seniority and knowledge. This is a unique case of the depiction of a pair of eye glasses in a Mughal painting which does not associate the spectacles with reading, writing and calligraphy which are problematic to a presbyope without a pair of convex lenses.

The final specimen is not a Mughal miniature, but an incomparably lively depiction of a great painter of Safavid Iran at work. He is Riza-i-Abbasi (1565-1635) whose image was painted on paper in water-colour, by his most famous pupil Muir in 1673 CE (fig.9). The painting now lies in the collection of Princeton University (USA). The artist is seated in a cross-legged posture, wearing white *jama* and a matching pyjama. Both these garments are only partially visible as the artist wears a brilliantly red flowing upper garment. As usual, he uses a black slash tied to his waist, offering a pleasing contrast to the bright red apparel. A short dagger is partially visible which is tagged to the sash. This is perhaps intended to indicate the elite position of the master artist. The artist also wears a blue turban. On his finely chiseled face are seen a fine pair of moustaches and a thin beard. On the nose rests a typical riveted pair of spectacles with which the artist closely looks at his work. He is an engaging artist engrossed in the painting of a framed figure of a person in European dress. Once again, the almost inseparable link between the painter and a pair of presbyopic lenses looms large here. Before the seated figure of Riza-i-Abbasi are also strewn a low stool, an ink-pot, a few small bowl-like objects probably containing colours.

These painted spectacles in Mughal miniatures leave no room for doubt about the acquaintance with the spectacles, at least among the master artists and elites in the Mughal court circle during the sixteenth and seventeenth centuties. We have already stated earlier that there is no indigenous knowledge-base nor manufacturing technology associated with the prescription and use of eye glasses for correcting problems of vision. It reached the subcontinent from the north Atlantic zone after 1500 CE when the European economic and political enterprises increasingly impacted both India and the Indian Ocean zone. However, once the technique of manufacturing eye-glasses gained ground in India, the possibilities of technology transfer increased, paving the way for local manufacture of eye-glasses. At the initial stage of indigenous manufacturing of eye-glasses in India, there were inevitable trials and errors. There are, therefore, records regarding the order of two pairs of spectacles at a time; it was not possible to grade and quantify vision in the early stages of spectacles manufacturing. I.G Khan presents documentary evidence of the loss of a fine *Firangi* (European) pair of spectacles with wooden frames in 1706 and the difficulty of obtaining suitable and matching lenses from local manufacturers in India. Qaiser, on the basis of the late eighteenth century evidence, suggests a thriving trade in locally made spectacles which gradually became affordable and moderately priced (probably half a rupee each)[35]. That there were notable augmentation of the technological level among Indian manufacturers of spectacles around the later part of the first half of the 18th century, is borne out by the encycloapedia named *Bahar-i-Azam* by Tekchand Bahar who was aware of different optical instruments and also of the spectacles (*chashma*)[36]. It is therefore apparent that the theories of vision and optics and the manufacture of spectacles reached the subcontinent from non-indigenous sources. But once the efficacy of eye-glasses to correct vision was established, its demand grew, at least among the elite groups and the literati. This paved the way for the indigenous manufacturing of the *chashma* after it had been introduced to South Asia by Occidental elements.

VII

Sustruta and Ophthalmology

It is relevant to take into account here the salient features of the understanding and treatment of eye-diseases in Indic traditions, especially in the Sanskrit medical treatises. Two outstanding medical treatises, respectively ascribed to Charaka and Susruta, clearly demonstrate the awareness of the diseases of the eye and their treatments. Without going into the problem of dating these two texts, one may broadly place the *Charakasamhita* during the Saka-Kushana phase of Indian history, i.e. during the early centuries CE. The *Susrutasamhita* is slightly later and possibly belongs to the 5th-6th centuries CE. The *Susrutasamhita* is distinctive by its highlighting surgical methods for the treatment of diseases, including those of the eye. There is little doubt that the *Susrutasamhita* was composed far earlier than the works of Ibn al Haytham.

According to Susruta, the eye, which "resembles the teat of a cow," is composed of five basic elements: the solid earth *(Bhu)* which forms muscles; heat *(Agni)* comes in the form of blood that flows through its veins/arteries; air *(Vayu)* makes the black part (iris/pupil); the fluid element *(Jala)* lies in the lucid part (vitreous), and the void (*Akasa)* represents the lacrimal ducts/ sacs for discharge of secretions. Anatomically, he outlines five subdivisions *(Mandalas)* of the eye: a) eye lashes *(Pakshma-mandala)*; b) eyelid *(Vartma-mandala)*; c)sclera/cornea *(Sveta/ Sukla mandala)*; d) choroid *(Krishna-mandala)* and e) pupil *(Drishti-mandala)*, The pupil "looks like a hole and is the size of a lentil seed." *Sandhis* represent the "joints" where these *mandalas* bind or connect. Eye diseases, caused by perturbation or imbalances in the three *doshas*, are listed below.

i. Caused by the perturbation of the wind (*vataja)* — 10 diseases

ii. Caused by the perturbation of the bile (*pittaja*) — 10 diseases

iii. Caused by the perturbation of the phlegm (*kaphaja*) — 13 diseases

iv. Caused by the affliction in blood (*raktaja*) — 16 diseases

v. Caused by the combinatory calamants (s*annipataja*) — 25 diseases

vi. Exogenous—2 types.[37]

Thus a total of 76 eye diseases were identified and enlisted by Susruta who diagnosed that out of these 76 diseases of the eye, 16 were incurable. The *Susrutasamhita* pays a particular attention to the diseases of the pupil (*drishti-mandala*)[38]. The pupil is described as being of the size of a lentil, having the shape of a hole and being covered by several layers. When perturbed *doshas* reached the eye through blood vessels and vitiate the first layer of the eye, the adverse effects on vision start. When the second layer of the eye is affected, the patient would begin to experience unreal visions of insects, banners, stellar movements, rains, clouds and darkness. Faraway objects would appear to the patient as near ones and the near ones as objects located far away. At this stage the patient would not be able to see the eye of the needle. As and when the lower part of the layer of the eye(s) became affected by the vitiating *doshas*, the person would suffer from the failure to see the near object; when the upper part of the layer became affected, it would lead to the problem of seeing distant objects; when a particular side of the layer was affected, then objects on that side could not be seen. In case the entire layer was affected all objects would appear jumbled up in the patient's vision. When the damage is located in the centre of the pupil, then a single object would appear as double in the patient's vision. When the damage is double, objects will appear as trebled; this leads to the cataract *(timira*) condition of the eye(s). Medical treatment for these ocular conditions was formulated in relation to which of the three *doshas* (either as individual or as combined calamant) was predominantly abnormal.

For the treatment of the 76 eye diseases, classified by Susruta, both medicinal and surgical—especially surgical treatments—are recommended by Susruta. Of the 76 types of eye diseases, Susruta recommended surgeries for 51 diseases, clearly showing his preference for surgical treatments for the majority of eye diseases. It is also notable that the text enlists 101 blunt and 20 sharp instruments of surgeries. The sharp instruments should ideally be so fine that it should be able to divide the hairs of the skin.

Susruta particularly underlines the treatment of cataract (*timira*) by surgical procedures. According to the Susrutasamhita, if the *timira* had reached the *linganasa* (prognosis of vision loss)stage, it is fit for surgical treatment provided the diseased part did not resemble a half-moon, sweat drop or a pearl; it was not fixed irregular and thin at the centre; is not streaked or variegated in colours and not painful. The surgery should be performed in mild weather; prior to the surgery lubricant therapy and fomentation should be done. The patient should be made to lie down on the floor and held firmly in position by attendants.

He should be asked to look at the tip of the nose steadily. The eyelids should be held wide open and at a point on the white circle of the eye two-thirds distance from the outer angle, and averting visible blood vessels, the surgeon should introduce a barley -tipped rod instrument, holding it firmly between the middle and index fingers and the thumb. The point of penetration into the eye should be exactly at the natural aperture, neither too low nor too high nor too much on one side or the other. The left eye should be punctured with the right hand and the right eye with the left hand. When the puncture is properly executed, a drop of clear fluid would emerge and a gentle sound would also be heard. Immediately thereafter the diseased part should be washed with breast milk and fomented with *vata*-relieving leaves, holding the rod in position all the while. At this stage the pupillary region of the black circle should be scraped with a rod instrument and mucoid material collected in the eye expelled by making the patient blow through the nose while closing the opposite nostril. Proper scraping would be shown by the glistening appearance of the black circle and absence of pain. The rod inserted and in position should be withdrawn gently at this time when the patient would have regained vision. The eye should be irrigated with ghee and bandaged with linen. The patient continue to lie supine and forbidden to cough, sneeze, yawn, spit or belch[39].

Susruta was also aware of the problems of a punctured vein during surgery. If it led to bleeding, the injury should be controlled by irrigating the eye with ghee processed with the breast-milk. In the case of a puncture too close to the outer corner of the eye, it could lead to swelling, pain, watering and congestion. Once again, irrigating the eye with ghee is recommended. If the puncture is too close to the black circle, redness and pain would occur, which should be treated with irrigation with ghee, blood-letting and purgation. In case of a puncture being made below the black circle, the symptoms would be severe pain, lacrimation, redness and a mucoid discharge when the rod is taken out. If the *timira* (cataract) is immature and pushed down it resumes its previous position with redness, severe pain and loss of vision.

In this above account of cataract surgery, modern ophthalmologists discern the extracapsular extraction of the cataract, something that preceded the modern surgical methods of Intra-ocular lens implant surgery or the phaco-emulsification surgery. Susruta is generally recognized as the first surgeon to have removed cataract with the depression method of couching by the anterior root[40].

VIII

Refractive State of the Eye: Emmetropia, Ammetropia and Different types of Ammetropia — Hypermetropia, Myopia, Aphakia

When parallel rays strike a physiologically normal eye they are refracted so as to converge upon the retina where they focus forming a circle of least confusion; when these ideal optical conditions occur with the eye in a state of rest the condition is termed Emmetropia.

The opposite condition of ammetropia, wherein the parallel rays of light are not focussed exactly upon the retina with the eye in a state of rest, is, therefore, much more common; such an eye has a refractive error.

Refractive errors may be of three main types: a principal focus may be formed by the optical system of the eye, but instead of being situated on the retina (as in emmetropia), it may be situated either behind it or in front of it. In the first case the eye is relatively too short,and the condition is then called hypermetropia (Diagram-1); in the second, it is relatively too long, when the term myopia is used.

Alternatively, the refractive system may be such that no single focus is formed as in the case where astigmatism is present.

These refractive anomalies can be caused by various conditions. Here briefly three conditions are mentioned for better understanding of this article.

1. The position of the elements of the system
    a. The antero-posterior diameter of the eye is too short,

and the retina is too near the optical system: Axial hypermetropia. (Diagram-3)

b. The anterior-posterior diameter of the eye is too long and the retina is too far away from the optical system: Axial myopia. (Diagram-4)

2. Absence of an element of the system

Absence of the lens, a condition known as aphakia, produces hypermetropia.Aphakia is an example of extreme refractive hypermetropia.

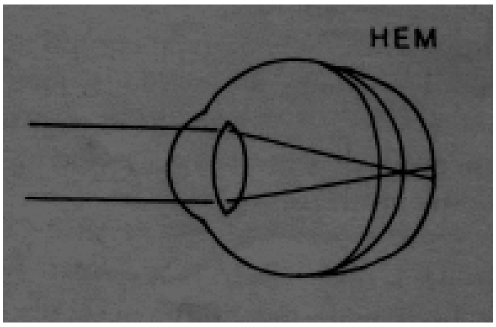

Diagram-1: Emmetropia (E), Hypermetropia (H) and Myopia (M) In Emmetropia (E), parallel rays of light are focused upon the retina. (after *Duke-Elder's Practice of Refraction,* Edinburgh, 1978: 29)

In hypermetropia (H), the eye is relatively too short, in Myopia (M),it is too long. Arrow shows the lens.

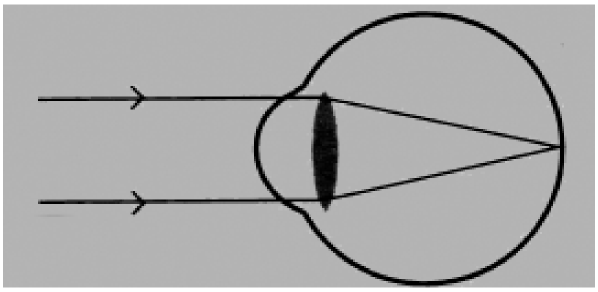

Diagram-2 Emmetropia. Parallel light rays from infinity focus to a point on the retina. (after Basic and Clinical Science Course, Section 3: *Optics, Refraction and Contact Lenses,* American Academy of Ophthalmology, San Fransisco, 1999: 112)

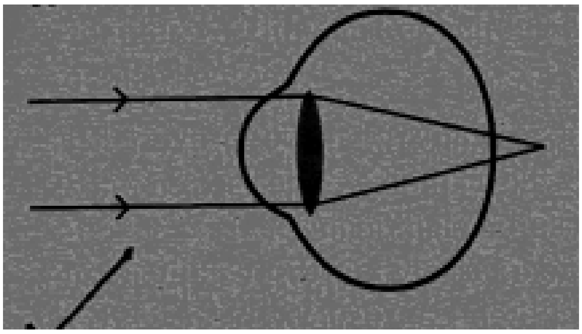

Diagram-3 Hypermetropia. Parallel light rays from infinity focus to a point posterior to the retina, forming a blurred image on the retina. (after Basic and Clinical Science Course, Section 3: *Optics, Refraction and Contact Lenses,* American Academy of Ophthalmology, San Fransisco, 1999: 113)

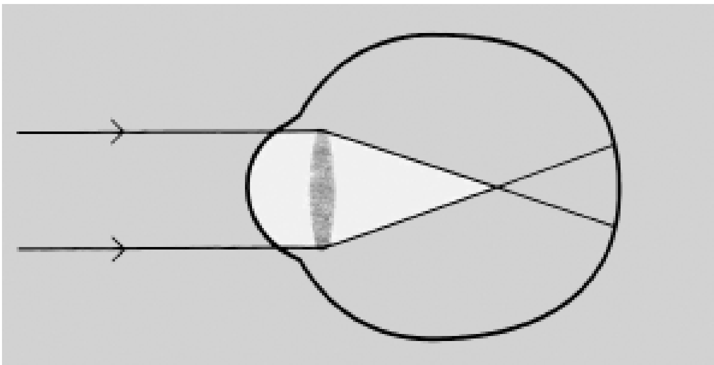

Diagram-4 Myopia. Parallel light rays from infinity focus to a point anterior to the retina, forming a blurred image on the retina. (after Basic and Clinical Science Course, Section 3: *Optics, Refraction and Contact Lenses,* American Academy of Ophthalmology, San Fransisco, 1999: 112)

Presbyopia

Presbyopia arises due to clinical accommodative problem. It needs special mention in this article. Presbyopia is the gradual loss of accommodative response resulting from loss of elasticity of the lens. This problem may manifest itself by blurring of near visual objects. Symptoms of presbyopia usually begin after the age forty years.

IX

Aphakia, the Disadvantages of Aphakia: Sustruta's Method of Cataract Surgery

Aphakia denotes an absence of the lens from the eye. The opposite term phakic describes an eye with its lens in place. An aphakic eye, as we have already discussed, is usually strongly hypermetropic. Following the treatise by Susruta and the various subsequent commentaries on it, the lens seems to have been removed by the couching method of operation, or by extracapsular/intracapsular method by anterior root in the vast majority of cases for overcoming the cataract-related problems of patients. And this type of cataract surgery by Susruta method is likely to have converted an operated eye into an aphakic eye.

In the absence of the lens, other things being normal, parallel rays of light are brought to a focus 31 mm behind the cornea, while the average anterior-posterior diameter of the eye is only 23 to 24mm. The dioptric system must therefore be usually supplemented by a strong converging lens, if the eye were emetropic, of about +10D.

The optical conditions in an aphakic eye are completely changed, for the dioptric apparatus has been reduced to a single refracting surface (the cornea) bounding a medium of uniform refracting index (the aqueous and vitreous humours). The nodal point of the eye would thus be moved forwards. The anterior principal focus, for example, is 23.22 mm in front of cornea instead of 17.05mm.

In the pre-modern times this strongly hypermetropic condition of an aphakic eye after a cataract surgery,therefore, needs correction by a strong converging lens/spectacles, about +10 diaptre, to give the patient the sight. The image in an aphakic eye, corrected by spectacles in their usual position, is about 25 per cent larger than when the eye is phakic. The difference of retinal image sizes between the phakic and aphakic optical state presents special problems to binocular vision in a patient where one eye has lens in situ and the opposite eye is aphakic[41].

X

Concluding Remarks: Aphakia, Cataract Surgery by Sustruta Method and Spectacles (Optics and Refraction)

Our foregoing survey and findings strongly underline that the concept of optics and refraction and the manufacture of spectacles as well were unheard of in the South Asian subcontinent before the 16th century. From the 16th century onwards, both textual and pictorial documentations indicate the growing familiarity with spectacles in the subcontinent, at least among the rulers, courtiers, elites and artists/ calligraphers. That spectacles reached India as imports from the Occident is quite apparent; the immense advantages of this device for the correction of refraction (Hypermetropia, Myopia, Presbyopia) seem to have been soon realized by the upper echelons of South Asian society. The optical difficulties of an aphakic eye are overcome only by wearing a pair of spectacles, or a contact lens, or by the insertion of an intra-ocular lens. But the couching method, the only available indigenous method of removing cataract in the pre-modern times, is likely to have converted the operated eye to an aphakic eye (i.e. an absence of lens from the eye). And in case of emmetrope and hypermetrope it only brings the numerous optical disadvantages of aphakia after such a surgery by couching method.

Therefore, one could very well raise a conceptual doubt that whether, how and to what extent the quality of vision in such an aphakic eye after cataract surgery could have been ensured by the couching method prior to the sixteenth century when refractive correction of an aphakic eye was unheard of in the subcontinent. Even while conceding the skill of cataract surgery by couching method laid down in the *Susrutasamhita*, it is unlikely that mere surgeries by couching method would have resulted in the desired quality of vision. It is high time to recognize the impacts of the theories of light and optics— emanating from Ibn al Haytham's concepts and the associated theories in Renascent Europe—and the subsequent advent of the spectacles through Occidental commercial networks from the sixteenth century CE onwards on the introduction of and familiarity with spectacles in South Asia.

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4 *Sabdachandrika* edited by P.V. Sharma, New Delhi, 1989; Chakrapanidatta's commentary on the *Charakasamhita*, namely *Ayurvedadipika*, has been edited along with the text of the *Charakasamhita* by Ram Karan Sharma and Bhagawan Dash, Varanasi, 1983; its English translation has been done by Bhagawan Dash, Varanasi, 2002

5 Vijaya Deshpande, 'Influences of India on Chinese Ophthalmology: A Case Study of Glaucoma', *Bulletin of the School of Oriental and African Studies*, vol. 62, 1999: 306-322; ibid., 'Ophthalmic Surgery: A Chapter in the History of Sino-Indian Medical Contacts', *Bulletin of the School of Oriental and African Studies*, vol. 63, 2000: 370-88

6 Savithri Preetha Nair,'Disease of the Eye:Medical Pluralism at the Tanjore Court in the Early Nineteenth Century, *Social History of Medicine,* February, 2012: 1-16. There had already been a sustained tradtion of building healing houses (*arogyasalas*) in South India at least since the eighth or ninth centuries CE. See Ranabir Chakravarti and Krishnendu Ray, 'Healers and Healing Inscribed, Epigraphic Bearing on Healing-houses in Early India', Occasional Paper no. 30, Institute of Development Studies, Kolkata, 2011

7 *American Academy of Ophthalmology, Basic and Clinical Science Course*, 1999-2000, section III (Optics, Refraction and Contact Lenses)

8 Mark A Smith, ''Mathematical Optics from the Antiquity to the 17th Century', in Ivor Grattan-Guinness ed., *Companion Encyclopaedia of the History and Philosophy of the Mathematical Sciences*, London and New York, 1994: 259-65

9 There is a voluminous literature on the celebrated medieval Islamic mathematician and scientist, Ibn al Haytham. We cite here a few references, but not a comprehensive bibliography on Ibn al

Haytham's contributions to mathematics, physics and optics. Edward Grant, *A Sourcebook of Medieval Science*, I, Cambridge (Mass), 1974; Nader El Bizri, 'Ibn al Haytham', in Faith Wallis ed., *Medieval Science, Technology and Medicine: An Encyclopaedia*, New York and London, 2005: 237-40; idem, 'Ibn al Haytham or Alhazen', in Josef W. Meri ed., *Medieval Islamic Civilization*, II, New York and London, 2006: 343-45; W. Arafat and H.J.J. Winter, 'The Light of the Stars: A Short Discourse by ibn al-Haytham', *The British Journal for the History of Science*, V.3, 1971 (June): 282-88.

10 David C. Lindberg, 'Alhazen's Theory of Vision and Its Reception in the West', *Isis*, LVIII.3, 1967: 321-41; Rosanna Gorini, 'Al Haytham, the Man of Experience: First Steps in the Science of Vision', *Journal of the International Society for the History of Islamic Medicine*, II.4, 2003: 53-55. For the English translation of the *Kitab al Manazir* with Commentary, see A.I Sabra (trn), *The Optics of Ibn al Haytham*, Books I-II-III (On Direct Vision), in two volumes, London, 1989. In more recent years Mark A. Smith prepared an English translation of the *De Aspectibus* which is the medieval Latin translation of Ibn al Haytham's *Kitab al Manazir*. See Mark A. Smith, 'Alhacen's Theory of Visual Perception: A Critical Edition with English translation and Commentary of the First Three Books of Alhacen's *De Aspectibus*', *Transactions of the American Philosophical Society*, 91 (4-5), 2001; also idem, 'Alhcen on the Principles of Reflection: A Critical Edition with English translation and Commentary of Books IV-VI of Alhacen's *De Aspectibus*, *Transactions of the American Philosophical Society*, 96 (2-3), 2006; idem, 'Mathematical Optics from the Antiquity to the 17th Century' in Ivor Grattan-Guinness ed., *Companion Encyclopaedia of the History and Philosophy of the Mathematical Sciences*, London and New York, 1994: 259-65 (important for the synopsis of the arguments). The principal facets of the mathematical findings of Ibn al Haytham are also available in the reviews of A.I. Sabra's work by Alexander Jones, 'Review of the Optics of Ibn al-Haytham, Books I-III: On Direct Vision', *Isis*, LXXXVII.4, 1991: 724-26. Also, George Saliba, 'The Optics of Ibn al-Hyatham, Books I-III, Direct Vision by A.I. Sabra, *Speculum*, LXVII, 1992: 977-80. An overview of the salient aspects of Ibn al Haytham's theories of vision and optics is also available in an excellent article by Iqbal Ghani Khan, 'Medieval Theories of Vision and the Introduction of Spectacles in India c. 1200-1750' in Deepak Kumar ed., *Disease and Medicine in India: A Historical Overview*, New Delhi, 2001: 27-40. We have heavily drawn upon Smith's and Khan's essays for our present paper.

11 David C. Lindberg, *Roger Bacon and the Origin of the Perspectiva in the Middle Ages*, Oxford, 1996; Iqbal Ghani Khan, 'Medieval

Theories of Vision', shows that the translation of al Haytham's original treatise into Latin paved the way for the Latin text's entry into the academic syllabi on Mathematics as early as 1572.

12 Kepler established how by the use respectively of convex and concave lenses as eye-glasses, presbyopia and myopia would be corrected. Before him, there is little evidence of the use of concave lens in spectacles to correct myopia. Vincent Ilardi, *Rennainsance Vision from Spectacles to Telescope*, Philadelphia, 2007: 244

13 Our discussions on Dioptrics and Catoptrics are largely based on Mark A. Smith and Iqbal Ghani Khan's essays (see note 8 above)

14 Iqbal Ghani Khani, 'Medieval Theories of Vision'

15 Iqbal Ghani Khan, 'Medieval Theories of Vision'

16 Ilardi, *Renaissance Vision*: 5

17 Ilardi, *Renaissance Vision*: 9. Spina (death 1311) was a friend of Giordano da Pisa

18 A. C. Crombie, *Robert Grossteste and the Origins of Experimental Science 1100-1700*, Oxford, 1971

19 Charles Singer et al, *A History of Technology*, vol. III, London, 1968

20 Tommaso da Modena was a mid-14th century CE Italian painter who was trained in Venice. He painted a series of portraits of Dominicans in Treviso. The portrait of Cardinal Hugh belongs to this group.

21 Edward Rosen, 'The Invention of Eye-Glasses', *Journal of the History of Medicine and Allied Sciences*, XI, 1956: 13-46

22 Ilardi, *Renaissance Vision*: 9

23 Iqbal Ghani Khan,'Medieval Theories of Vision'

24 Joseph Needham, *Science and Civilization in China*, IV.1, Cambridge, 1962: 115

25 P.K. Gode, 'Some Notes on the Invention of Spectacles', in idem, *Studies in Indian Cultural History*, III.2 Poona, 1969: 102-12, especially, 106-7; this article is also cited and used by Iqbal Ghani Khan. Gode points out that Somanatha Kavi wrote on the life of Vyasaraya (1446-1539). In this context the poet mentioned *upalochangolaka* which was used at the time of reading a manuscript. Gode also recorded the use of the term *chalisa* or *chalase* in the 17th century *Dasabodha* of Ramadasa to denote eye glasses. The term probably stands for eye glasses with convex lenses used by presbyopes, usually after the age of 40. That is why, perhaps the term *chalisa* (40) is used here as a synonym of spectacles. Gode moreover noted the use of the term *upanetra* in the *Yatharthadipika* of Vamanapandita (1636-95 CE). As the

upanetra was meant for seeing what eyes cannot see, the term certainly denotes spectacles and is synonymous with *upalochanagolaka*.

26 As the title of Khan's paper would show he tried to trace the theories of vision and the use of spectacles in India during the five and a half centuries (1200-1750). He has also highlighted the possibilities of the transfer of scientific knowledge from Iran and West Asia with the onset of the Delhi Sultanate from early thirteenth century. It is however difficult to prove the use of spectacles in South Asia prior to the 16th century, in the light of the available textual and pictorial evidence.

27 For the art-historical discussion on this painting see Amina Okada, *Imperial Mughal Painters: Indian Miniatures from the Sixteenth and Seventeenth Centuries*, Paris, 1992: 5; also see A. S. Melikian Chirrami, 'Mir Sayyid Ali: Painter of the Past and Pioneer of the Future, in Asok Kumar Das ed, *Mughal Masters* 1998 : 39-40.

28 See Asok Kumar Das, *Mughal Painting during Jahangir's Time*, Calcutta, 1978, plate 8b

29 Unlike the painters, sculptors and architects of pre-Mughal times, who often remained anonymous, the Mughal painters were mostly literate. It is a regular feature with the Mughal miniatures that the names and signatures of not only the principal artist (*ustad*), but also that of the calligrapher and the applier of painting were recorded in the painting. No less significant is the fact that the artist was often himself the subject of portrayal in the Mughal painting, sometimes as the principal figure, or as an ancillary figure in courtly gathering. S.P. Verma, *Mughal Painters and Their Works: A Biographical Survey and Comprehensive Catalogue*, New Delhi, 1994.

30 For the study of this painting see Asok Kumar Das ed., *Mughal Masters, Mumbai,* 1998 : 110.

31 The image is taken from Amina Okada, *Imperial Mughal Painters: 161-163*.

32 This painting, now in the India Office Library collection, is taken from Amina Okada, *Imperial Mughal Painters*

33 The image is taken from Amina Okada, *Imperial Mughal Painters : 175.*

34 For the importance of *jharokha* in the politics and court culture of the Mughal times, see Harbans Mukhia, *The Mughals of India*, Oxford, 2004

35 A.J. Qaisar, *Indian Responses to European Technology*, New Delhi, 1980

36 Iqbal Ghani Khan, ‘Medieval Theories of Vision’

37 Valiathan, *Susruta*: 514-24

38 Valiathan, *Susrut*a: 543-50

39 Valiathan, *Susruta*: 547-48

40 See in this context, K.B. Kansupada and J.W Sasani, ‘Susruta, the Father of Indian Surgery and Ophthalmology’, *Documenta Ophthalmologica*, 93, 1997: 119-67; also C. Srinivas, ‘Visual Disorders in Ancient Indian Science’, *Bulletin of the Institute of the History of Medicine*, 23, 1993: 101-11; S.V. Raju, ‘Susruta of Ancient India’, *Indian Journal of Ophthalmology*, LI, 2003: 119-22. Both the *Charakasamhita* and the *Susrutasamhita* discuss various diseases of the eye and their treatments from the point of the three *dosh*a theory which is of foundational importance in Ayurveda. In other words, the diseases of the eye have their genesis in wind (*vata*), bile (*pitta*) and phlegm (*sleshma* or *kapha*). With this are to be added the variety called s*annipatika* which denotes diseases on account of the combination of more than one *doshas.* Before classifying the diseases of the eye according to the two medical texts, we take into account the general principles of three *dosha* theory in Indian medical treatises. The very term *dosha* (*tocham* in Tamil Siddha medical texts) literally stands for fault. However, the term *dosha* has been more cogently taken by Zysk to mean the three vitiating forces in the body, namely wind, bile and phlegm (Tamil Siddha medical texts used the three terms *vata, pittam* and *chillettumam* corresponding respectively to *vata, pitta* and *sleshma*). In the *Charakasamhita* (*Sutra-sthana* 7.39-41) the term *dhatu* is definitely conterminous with the three *doshas* or calamants. The three *doshas*, wind, bile and phlegm, may further be riled (*kopana*), and therefore can lead to illness. Most of the medical treatises, including the *Charakasamhita*, strongly recommended calming or removing or destroying the faults. The *Charakasamhita* further theorizes on the diseases and the degree of difficulty of treatment in relation to the affectation by the three *doshas*. Thus three outcomes are possible: a) if the disease is caused by one fault *(dosha*) then the cure and treatment would be easy (*sukha-sadhya*); b) if afflicted by two faults, then the cure becomes difficult (*krichhra-sadhya*) or palliable (*yapya*). c) But if the disease was caused by three faults (*tri-doshaja*), then it is beyond cure and the treatment is to be refused (*pratyakhyeya).*

The *Susrutasamhita*, however, suggests some departures from the earlier texts in an innovative manner. Susruta seems to have been in favour of intentional strengthening of the faults, rather than the calming of the same following the earlier tradition of medical treatment. He leaves a hint that the three faults were essential and even beneficial in the make-up of the human body. That is why, he recommends that the ideal balance of the three *doshas* should have been preserved and a diminished fault (*vayu, pitta* or *kapha*) must be enhanced. This clarifies his opinion that imbalance (*vaishamya*) of wind., bile and phlegm caused illness. The *Susrutasamhita,* therefore, recognizes that the three faults, in their balanced states, provided the basis of the healthy body. Scharfe rightly diagnosed here a semantic development of the term *dosha*—first meaning affliction or more precisely, pathological affliction of wind, bile and phlegm; then denoting a common term for these components of the body; and finally in the *Susrutasamhita* signifying the very basis of the healthy body. See Hartmurt Schrafe, 'The Doctrine of the Three Humours in Traditional Indian Medicine and the Alleged Antiquity of Tamil Siddha Medicine', *Journal of the American Oriental Society*, 119, 1999: 609-629. Also G.J. Meuelenbeld, 'The Characteristics of a *Dosha*', *Journal of the European Ayurvedic Society*, 2, 1992. Also Zysk, 'The Evolution of Anatomical Knowledge in Ancient India' (see note 4)

41 Duke Elder, *Practice of Refraction*, Revised by David Abraham, Edinburgh, London and New York, 1978 (9th edition)

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Fig. - 1

Fig. - 2

Fig. - 3

Fig. - 4a

Fig. - 4b

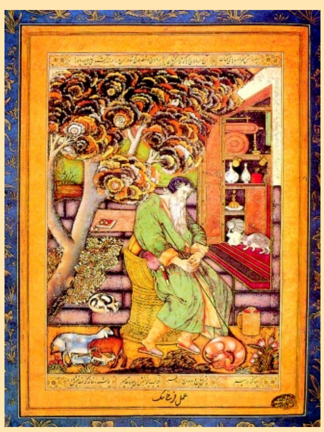
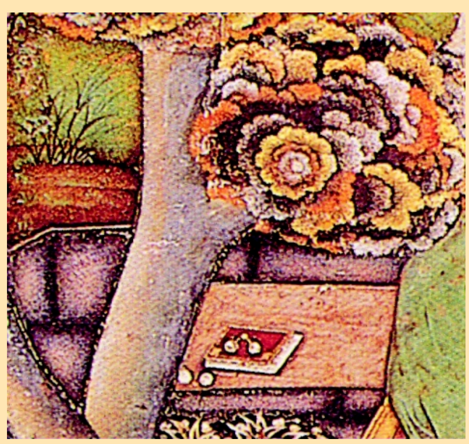


Fig. - 5a

Fig. - 5b



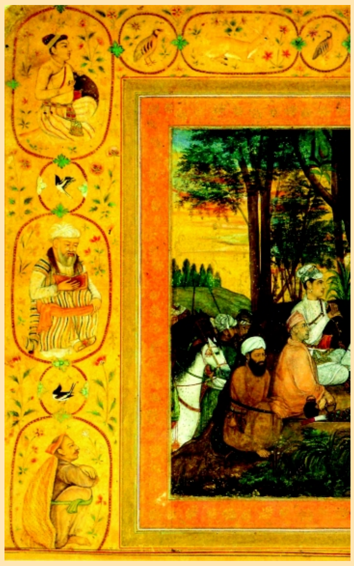


Fig. - 6

Fig. - 7a

Fig. - 7b

Fig. - 8a

Fig. - 8b

Fig. - 9