




# Myopia in India

Amar Pujari , Sujeeth Modaboyina, Divya Agarwal, Gunjan Saluja, Rajeswari Thangavel, Vaishali Rakheja, Rohit Saxena , Namrata Sharma , Jeewan S Titiyal, Atul Kumar

Dr Rajendra Prasad Centre for Ophthalmic Sciences, All India Institute of Medical Sciences, New Delhi, India

Correspondence: Amar Pujari, Dr Rajendra Prasad Centre for Ophthalmic Sciences, All India Institute of Medical Sciences, Room no. 212, RPC-I, AIIMS, New Delhi, India, Email dramarpujari@gmail.com

**Abstract:** India is a culturally and geographically diverse nation. Its vast demographic nature does not allow a single definition for any of the given medical conditions in its territory. One important clinical condition which has created an uproar in the rest of the world is myopia. Its cause, prevalence, etiopathogenesis and other factors are being explored constantly; however, data with respect to Indian subcontinent are genuinely missing. Hence, in this review, we enumerate the country's myopia journey from last 4 decades. The epidemiology, genetics, ocular/systemic association, quality of life, imaging, and management in myopia with necessary future directives are discussed to augment the overall management in future.

**Keywords:** myopia, India, myopia in India, atropine therapy in myopia, genetics and myopia, retinopathy of prematurity and myopia, imaging in myopia, management of myopia

## Introduction

Myopia is a common refractive error. It is also an important cause of ocular morbidity especially in younger generations like school-going children and young adults.<sup>1</sup> It has become a major public health problem globally, with a prediction of up to 50% of the world population will be myopic by 2050.<sup>2</sup> Uncorrected myopia can have huge social, psychological, economic, and developmental implications.<sup>1</sup> In addition, due to the degenerative changes in the retina and the optic disc, the irreversible vision-threatening sequel seems inevitable.

India is the second most populated country in the world, with around 41% of its population (492 million) being less than 18-years of age. This young population is an important asset for the nation's development, and their challenges need to be addressed on time. While rising myopia is a cause of concern, it is not being given due importance in India due to a paucity of scientific literature in Indian set ups.<sup>3,4</sup> Nevertheless, there is also a definitive role of genetics and environmental factors in the pathogenesis of myopia in Indian eyes; therefore, the present review aims to bridge the knowledge gap by providing a detailed report on myopia from last 40 years.

## Methods

A detailed literature search was conducted on PubMed/Medline, Scopus and Web of science using the keywords "myopia", "myopia in India", "myopia prevalence", "myopia treatment", "myopia and genetics", "imaging in myopia", and "myopia and its associations". With this, more than 1000 articles were encountered, out of which only dedicated studies assessing the myopia-related entities in India eyes were included, whereas rest were excluded. A total of 113 studies satisfied our criteria, which were then assessed in detail to note their objective, clinical relevance, and conclusions. The review process was segregated into epidemiology, genetics, retinopathy of prematurity, ocular and systemic association, quality of life, imaging, and management sections for better understanding. Nevertheless, future directives were also proposed at the end to optimize future research works.

## Observations

### Epidemiology

Epidemiological studies have observed the magnitude of myopia in a defined population within certain age group or in a region. India being a diverse country, every state has its own lifestyle, geography, and many other micro and macro differences, hence, the reported studies need to be analyzed on an individual basis. By keeping these views, we broadly discuss the India's myopia literature under six different regions that are relatively homogenous, these include the South zone, Central zone, East zone, West zone, North zone, and Northeast zone<sup>5</sup> (Table 1).

#### South Zone

The southern states of India have a relatively well-developed medical infrastructure as compared to the rest of the country. Hence, maximum number of epidemiological studies were from this zone, here, a total of 12 studies were noted between 1997 and 2019.<sup>6–17</sup> This can be noted in Table 1.

Of the seven studies conducted in Andhra Pradesh/Telangana, 4 were population-based, 2 were school-based and 1 was hospital-based. The prevalence in the population-based studies varied between 3.6% and 36.5%, whereas the school-based, and the hospital-based studies had a prevalence rate of 7.5% to 8.6%, and 9%, respectively.<sup>6–12</sup> To note, most of these studies included the population of less than 40 years of age except for the hospital-based studies.

Karnataka and Tamil Nadu states had 2 studies each.<sup>13–16</sup> The prevalence rate in children between 5 and 16 years of age varied between 4% and 11.5% in the 2 school-based studies conducted in Karnataka.<sup>13,14</sup> In Tamil Nadu's

**Table 1** The Details of Prevalence of Myopia in India Along Various Zones

Zonal Division	Reference	Place	Type of Study	Age Group (Years)	Prevalence
South Zone	Kalivayalil <sup>6</sup> (1997)	Hyderabad	School	3–18	8.6%
	Dandona <sup>7</sup> (1999)	Hyderabad	Population	–	4.44% (<15 years) 19.39% (>15 years)
	Khan <sup>8</sup> (2000)	Hyderabad	Hospital	0–60	9% (Degenerative myopia)
	Dandona <sup>9</sup> (2002a)	Hyderabad, West Godavari, Adilabad, Mahbubnagar	Population	0–15	3.6%
	Dandona <sup>10</sup> (2002b)	Mahbubnagar	Population	7–15	4.1%
	Raju <sup>15</sup> (2004)	Thiruvallur and Kancheepuram	Population	>39	26.99%
	Prema <sup>16</sup> (2008)	Thiruvallur and Kancheepuram	Population	>39	31% (Rural) 17% (Urban)
	Krishnaiah <sup>11</sup> (2009)	Hyderabad, West Godavari, Adilabad, Mahbubnagar	Population	>39	36.5%
	Uzma <sup>12</sup> (2009)	Hyderabad	School	7–15	7.48%
	Bansal <sup>13</sup> (2012)	Kolar	School	6–16	11.5%
	Joseph <sup>17</sup> (2018)	Pondicherry	Population	>39	35.6%
	Prabhu <sup>14</sup> (2019)	Udupi	School	5–15	4%
Central	Chandra <sup>18</sup> (1982)	Allahabad	School	8–16	16.43%
	Haq <sup>19</sup> (2009)	Aligarh	Population	>19	11.5%
	Agrawal <sup>20</sup> (2020)	Raipur	School	5–15	3.21%

(Continued)

Table I (Continued).

Zonal Division	Reference	Place	Type of Study	Age Group (Years)	Prevalence
East					
	Datta <sup>22</sup> (1983)	Kolkata	School	5–13	0.89%
	Das <sup>23</sup> (2007)	Kolkata	School	5–10	14.02%
	Bagchi <sup>24</sup> (2008)	West Bengal	School	5–15	2.85%
	Ghosh <sup>25</sup> (2012)	Kolkata	School	6–14	11.23%
	Rao <sup>26</sup> (2018)	Bhubaneswar	Hospital	6–17	24.8%
	Warkad <sup>27</sup> (2018)	Bhubaneswar	School	6–17	0.63%
	Panda <sup>28</sup> (2020)	Rayagada	School	5–15	4.9%
West	Padhye <sup>29</sup> (2009)	Pune	School	5–15	2.15%
	Basu <sup>32</sup> (2011)	Surat	School	7–15	13.9%
	Nangia <sup>30</sup> (2010)	Nagpur	Population	>29	17%
	Jonas <sup>31</sup> (2017)	Nagpur	Population	>30	15.3%
North zone	Murthy <sup>33</sup> (2002)	Delhi	Population	5–15	7.4%
	Ahmed <sup>36</sup> (2008)	Srinagar	School	6–22	4.74%
	Jha <sup>37</sup> (2008)	Leh	School	3–15	4.1%
	Saxena <sup>34</sup> (2015)	Delhi	School	5–15	13.12%
	Shukla <sup>35</sup> (2018)	Delhi	School	9–12	2.5%
	Singh <sup>38</sup> (2019)	Gurugram	School	5–15	21.1%
North East zone	Natung <sup>39</sup> (2017)	Shillong	Hospital	5–88	27.4%

population-based studies in the age group of more than 39 years, the prevalence rate varied between 17% and 31%.<sup>15,16</sup> In an isolated study from Pondicherry on more than 39-year-old subjects, a prevalence rate was noted to be around 35.6%.<sup>17</sup> Nevertheless, in Prema et al observation, the prevalence rate was noted to be more in rural areas (31%) than in urban areas (17%).<sup>16</sup> Hence, in brief, within the south zone states, the prevalence of myopia was variable within a variable subjective profile.

### Central Zone

There were 3 studies from the central zone.<sup>18–20</sup> Among the two Uttar Pradesh state studies, a school-based study in 8–16-year-old children noted a prevalence of 16.43% and a population-based study in subjects more than 19 years of age noted a prevalence of 11.5%.<sup>18,19</sup> On the contrary, a lower prevalence of 3.21% was observed in the Chhattisgarh state's school-based study in 5–15-year-old subjects.<sup>20</sup>

### East Zone

The eastern region of India had 8 studies.<sup>21–28</sup> In West Bengal state, the prevalence in 4 school-based studies (age 5–14 years) varied between 0.89% and 14%, while it was 22% in newborn myopic screenings.<sup>22–25</sup> The 2 school-based studies from Orissa state noted a prevalence of 0.63% to 4.9% in 5–17-year-old children, while a higher prevalence of 25% was observed in a hospital-based study in a similar age group (6–17 years).<sup>26–28</sup>

## West Zone

The West zone had 4 studies, of which, 3 were from Maharashtra and 1 from Gujarat.<sup>29–32</sup> The prevalence of myopia in 2 population-based studies from Maharashtra in the age group of 29 years and above was found to be 15.3% and 17%. The school-based study noted a prevalence of 2.15% in 5–15-year-old subjects.<sup>29,31,32</sup> The Gujarat state study discovered a prevalence rate of 13.9% in 7–15 years old subjects.<sup>32</sup>

## North Zone

The north zone inherits the country's capital and had six epidemiological studies on myopia. Among these, 3 were from the national capital Delhi, 2 from Jammu and Kashmir, and 1 from the state of Haryana.<sup>33–38</sup> The 2 school-based studies from Delhi which included 5–19-year-old subjects, documented a prevalence of myopia from 2.5% to 13%. The third population-based study noted a prevalence of 7.4% in 5–15-year-old subjects.<sup>33–35</sup>

The two studies from Jammu and Kashmir were school-based and noted a prevalence of 4.1% to 4.74% in 3–22-year-old subjects.<sup>36,37</sup> The isolated school-based study from Haryana noted a prevalence of 21.1% between 5–15-year-old subjects.<sup>38</sup>

## North-East Zone

There was only one study from the northeast zone which comprises seven states. It was a hospital-based study from Meghalaya with a prevalence of 27.4% in 5–88-year-old subjects.<sup>39</sup>

## Genetics of Myopia in India

Conventionally, myopia has been thought to have a polygenic inheritance with variable expressivity and a gene dosage effect. In India, the diverse geo-biological variations including genetics as well as various social factors seems to play a crucial role in the development of myopia. However, some of these factors may even be protective against myopia. Therefore, several observations have been made in Indian eyes to understand the reliable nature of genetic association in myopic eyes.

In a study from the west zone, Basu et al observed 92 families of a Shia Muslim community. A higher frequency of myopia was noted among male offspring with a consanguineous marriage history.<sup>40</sup> In another combined study from the west and south zone, an X-linked inheritance pattern was discovered. The non-syndromic myopic mutations along pseudo-autosomal regions of distal Xq28 and other proteins were described in this study.<sup>41</sup>

From the south zone, observation on the role of Membrane frizzled-related proteins (MFRP) and the visual system homeobox protein (VSX2) gene variants showed a variable influence of these proteins on the axial lengths.<sup>42</sup> However, a study on the role of the vitamin D receptor gene in high myopic eyes did not reveal any significant clinical associations.<sup>43</sup>

Gupta et al conducted a study in the north zone and investigated the frequency of CYP1B1, p.E229K and p.R368H mutations in juvenile-onset open-angle glaucomatous eyes (JOAG), but they did not discover any major differences in moderate to high myopic eyes with or without such mutations.<sup>44</sup> From Kashmir, the potential role of TGIF1 and the TGFB1 genes in myopia has been studied but again with variable significance.<sup>45,46</sup>

From the east zone, the relation between sickle cell disease and the refractive errors was investigated, where Shukla et al discovered a total of 63% prevalence of myopia in patients with sickle cell disease. Furthermore, the *L4* 70-bp VNTR genotype in these patients showed an increased risk for the development of refractive errors but it was statistically insignificant. However, *NOS3* 27-bp VNTR genotypes showed a reduced risk of myopia in these eyes.<sup>47</sup>

Hence, the association of myopia with specific genes is less clear as of now. This is because of lesser number of genetic studies as well as due to more diverse subject profile.

## Myopia and Retinopathy of Prematurity

In premature babies, the incidence of refractive error is higher, myopia to be more specific. In an observation on 50 pre-term babies by Verma et al, the incidence of myopia was around 16% at the end of 1 year, and this association was higher with decreasing weight. Similarly, an inverse relationship was observed between the incidence of refractive errors and gestational age.<sup>48</sup> Since then, there have been several observations about the increased risk of myopia in babies with

retinopathy of prematurity (ROP), both in mild and severe cases.<sup>48–50</sup> The risk of developing myopia increased with increased clock hours of ROP, the higher number of laser spots, and prolonged regression times.<sup>49–51</sup> Some authors found myopia to be more common in laser-treated eyes as compared to the spontaneously regressed ROP cohorts, with cicatricial retinopathy hypothesized to be a risk factor in laser-treated eyes.<sup>52–54</sup> In addition, the altered role of neuroectodermal components in ROP has been proposed to be a risk factor.<sup>55</sup> However, concrete reasons for the development of myopia in laser-treated eyes are yet to be discovered, with the most accepted theories attributing it to steep keratometry, greater lens thickness, the forward position of the lens centre and shallow anterior chamber.<sup>56–58</sup>

## Myopia and Other Associations/Co-Morbidities

### Ocular Associations/Co-Morbidities

It is essential to understand the ocular and systemic associations of myopia for its comprehensive management. In literature, the primarily noted association is glaucoma. In a study on congenital glaucomatous eyes operated under 1 month of age, myopia was observed in almost half of the patients.<sup>59</sup> Due to the complex and indiscriminate changes along RNFL and optic nerve head in both myopia and glaucoma, myopia adds to the complication in the diagnosis and management of open-angle glaucoma in the later years of age.<sup>60</sup> The glaucomatous optic disc also poses difficulties in the treatment of patients with myopic disc changes. In addition, myopia has been said to affect visual recovery in early age groups.

The second most common association was the co-existence of myopia with retino-choroidal diseases. In a study by Pan et al, it was noted that myopia and a definite change in each millimeter of axial length (AL) provided a finite protection against diabetic retinopathy and age-related macular degeneration (1.6% in myopic eyes as compared to 3.3% in emmetropic eyes).<sup>61</sup> A retrospective observational study to unveil the associations between central serous chorioretinopathy and myopia noted a reduced incidence of central serous chorioretinopathy in myopic eyes as compared to emmetropic eyes.<sup>62</sup> The next common association was cataract changes in myopic eyes. Pan et al had noted a greater likelihood of nuclear cataract and posterior subcapsular cataract in myopic eyes. A finite increase in the axial length was found to be associated with subcapsular cataracts, and not with the nuclear or cortical cataracts.<sup>61</sup> Similarly, few other studies also observed myopia to influence the development of nuclear cataracts as compared to posterior subcapsular, cortical and other forms of cataracts.<sup>63,64</sup> A study from our centre documented the progression of unilateral axial myopia following cataract extraction in younger age groups.<sup>65</sup>

Rarer associations include the presence of myopia in blepharophimosis epicanthus inversus syndrome (BPES), variability in subjective and objective refraction in myopic eyes due to accommodative spasm and the presence of amblyopia.<sup>66–71</sup>

### Systemic Associations/Co-Morbidities

Apart from ocular co-morbidities, myopia can also have systemic or syndromic associations. Myopia has been observed in beta-thalassemia patients in varying proportions, along with retinal morphological and functional changes.<sup>72</sup> In another study, the prevalence of inherently longer eyes in taller subjects was noted (but not necessarily myopic).<sup>73</sup> The role of prenatal sex steroid exposure as the possible cause for myopia has also been demonstrated with some evidence.<sup>74</sup> Limited observations have shown the presence of myopia in patients with other systemic disabilities like hearing loss, cerebral palsy, down syndrome, mental retardation and learning disabilities.<sup>75–81</sup>

## Myopia and Quality of Life

The children with uncorrected refractive errors are likely to face difficulty in all spheres of life, including copying text from the blackboards in classrooms.<sup>82</sup> Myopia can also be a frequent cause of headache in children apart from school or educational-content-related concerns.<sup>83</sup> As we know, handwriting is a visual-motor skill, and due to uncorrected or even optimally corrected refractive errors, the subjects could still face many practical difficulties during reading (due to letter-size/line variation during reading), during academic achievements and exams. Moreover, excessive near work itself can act as an aggravator for myopia progression.<sup>84</sup> Therefore, school teachers and parents must be made aware of these difficulties, so that they can undertake quality care of the child for overall wellbeing.<sup>85,86</sup>

Apart from these, in Indian society, there is still a social stigma attached to spectacle usage in public. This has led to discouragement for spectacle use within emotionally weaker individuals. To address this concern, provisions for peer understanding/appreciation should be mandated to improve the overall psychological well-being of the society. Similarly, medical conditions like amblyopia, retinopathy of prematurity and other diseases must be addressed optimally before spectacle prescription.<sup>87,88</sup> Also, the contact lens or the spectacle cost could be another barrier and as of now we do not have definite cost estimates available in India, but still, economic, and social burden are major concerns that need appropriate attention.

## Myopia and Ocular Imaging

In myopic eyes, almost all the ocular tissues can be affected, and to know such clinically relevant changes, several non-invasive tests are being conducted.<sup>89</sup> These tests are on the constant rise in recent past (Table 2).

### Corneal and the Anterior Scleral Imaging

The corneal biomechanics have been stated to be altered in myopic eyes in varying proportions.<sup>90</sup> The greater radius of corneal curvature has been attributed to longer axial lengths, lower educational levels, and the lower prevalence of high myopia.<sup>91</sup> Apart from this, the differential thickness of anterior scleral layers (inferior > superior), and its unequal change (inferior > superior) with increasing myopia has also been documented.<sup>92</sup> However, their clinical relevance in daily practice with definitive therapeutic implications are yet to be discovered.

### Retinal and Nerve Fiber Imaging

The moderate (−4 to −8D) and high (>−8D) myopic eyes have been observed to have progressively thinner retinal nerve fibre layer as compared to emmetropic eyes.<sup>93</sup> Abnormally high RNFL thickness in high myopic eyes on scanning laser polarimetry has been emphasized, where false perception can change the treatment strategy.<sup>94</sup> This becomes crucial while addressing glaucomatous eyes with myopia where RNFL thickness can hinder the accurate management of glaucoma.<sup>95,96</sup>

Associated retinal changes in the form of foveal and macular thickness variability with increasing axial length are also possible. The retinal morphology seems to be thinner with increasing axial length and myopic refractive error, but in cases of high myopia, the possibility of higher thickness must also be kept in mind as the vitreomacular tractions can lead to elevated macular/foveal thickness parameters.<sup>97</sup> Furthermore, a vigilant and careful watch for pathological lesions irrespective of the amount of myopia is also equally important.<sup>98,99</sup>

### Choroidal Imaging

Choroid like retina has also shown to possess some of the crucial vision-threatening changes. In an observation on 5–17-year-old children, Matalia et al noted relatively increasing choroidal thicknesses and its volume with increasing myopia.<sup>100</sup> And under such necessities, swept-source optical coherence tomography seems to be more reliable for choroidal imaging due to its deeper penetrating abilities.<sup>101</sup> Overall, the tool could be of any kind, but the intention should be directed towards the identification of vision-threatening changes at the earliest.<sup>102</sup>

## Management of Myopia

### Spectacles

Spectacles are the most accepted form of intervention for all age groups of myopia in India, and to achieve this, periodic refraction under appropriate cycloplegic agent is advocated. However, many factors are hindering the much-needed universal spectacle coverage despite adequate funding. In India, lack of easy access to regular refractive services and lack of availability of spectacles are the major concerns in resource deficient areas, and within the adequately resourced areas, lack of public interest remains the major cause of concern.

Primarily, to understand the overall spectacle need and the coverage, Marmamula et al from southern India conducted a study on more than 40-year-old subjects. They noted that, overall, only around 30% of the subjects' used spectacles for their need.<sup>103</sup> Similarly, from northern India, Malhotra et al discovered the spectacle coverage to be around 33%.<sup>104</sup> In

**Table 2** The Details of Imaging Studies on Myopic Eyes in India

S. No.	Reference	Structure Analyzed	Age Group (Years)	Instrument	Key Findings	Conclusion
1	Matalia J et al <sup>100</sup> 2018	Retinal and choroidal thickness and volume along with choroidal vessel volume.	5–17	SD-OCT (Optovue, Inc., CA, USA)	1.The foveal thickness, choroidal volume and the choroidal vessel volume had a significant increment with higher degrees of myopia.	In paediatric population, the myopia has higher effects on retino-choroidal changes than the age.
2	Bhayana <sup>101</sup> AA et al 2019	Choroidal layer.	19–60	SS-OCT (DRI-OCT Triton plus, TOPCON, Tokyo, Japan)	1.Subfoveal choroidal thickness had significant positive correlation with refractive error and negative correlation with axial length.	Normative data of choroidal and retinal thickness were estimated using SS-OCT.
3	Dada T et al <sup>94</sup> 2013	Retinal nerve fiber layer.	18–40	GDxVCC (Carl Zeiss Meditec, Dublin, CA)	1.While assessing and monitoring glaucomatous damage in moderate to high myopes on GDxVCC, peripapillary chorioretinal atrophy and scleral birefringence can contribute to falsely higher RNFL values in high myopic eyes.	Myopia in glaucomatous eyes need careful evaluation.
4	Singh D et al <sup>93</sup> 2017	Retinal nerve fiber layer.	20–34	Cirrus HD-OCT (Carl Zeiss Meditec, Inc., Dublin, CA, USA)	1.Emmetropic eye (91.26 $\mu$ ) had higher RNFL thickness compared to moderate (83.76 $\mu$ ) and high myopic eyes (78.68 $\mu$ ).	High myopes have inherently thinner RNFL, hence, glaucoma in these eyes need careful and comprehensive approach.
5	Malakar M et al <sup>95</sup> 2015	Retinal nerve fiber layer.	11–40	Fourier domain OCT	1.Mean RNFL thickness was lower in high myopes (87.89 $\mu$ ) as compared to the control group (111.64 $\mu$ ).	Myopic eyes need special consideration while evaluating for glaucoma.
6	Dhakar R et al <sup>92</sup> 2020	Anterior scleral thickness.	15–35	SS-OCT (Topcon, Tokyo, Japan)	1.The mean anterior sclera thickness was thickest in the inferior region (605.9 $\mu$ m) and thinnest in the superior region (475.3 $\mu$ m). 2.And the inferior anterior scleral thickness decreased with an increase in degree of myopia.	Anterior scleral thickness in the inferior region can act as a marker for myopia progression.
7	Venkatesh R et al <sup>102</sup> 2020	Choroidal layer	18–85	SD-OCT (Spectralis)	1.Intra-choroidal cavitation was seen in more than half of high myopic eyes.	The macular or peripapillary intra-choroidal cavitation should be screened in high myopic eyes.
8	Samuel NE et al <sup>97</sup> 2015	Foveal and macular thickness	20–40	OPTOS SPECTRAL OCT/SLO	1.Low and moderate myopes had thinner fovea compared to high myopes. 2.The axial length had a positive correlation with the fovea minimum, fovea and superior inner macular thickness.	Early detection of macular changes can be evaluated by OCT and used as a screening tool in young myopes.

this study, further exploration revealed that around 66% of subjects did not perceive the need for glasses.<sup>104</sup> Furthermore, Gupta et al also proposed the evidence of better spectacle coverage with subsidized prescriptions.<sup>105</sup>

In school children, Morjaria et al conducted two studies.<sup>106,107</sup> In the first study, the differences between custom made and ready-made glasses were compared, and in the second study, novel educational interventions were evaluated apart from spectacle correction. In a later study, it was discovered that the education of the parents through phone calls and other technical means did not yield any superior results.<sup>107</sup> Various reasons were proposed for this, of which ignorance remained the major obstacle in achieving desired results. To improve upon this, Ravilla et al highlighted a few important and viable solutions including outreach camps and community centres.<sup>108</sup> Hence, cumulatively, these aspects need further research and critical thinking which include education and awareness about the need for spectacles, countermeasures to bullying and social humiliations, and parental education through available technology and media platforms.

### Orthokeratology

The next investigated modality of treatment in myopic eyes includes orthokeratology. In general, orthokeratology means the reduction or modification or elimination of refractive error with the help of programmed contact lens application. Basically, with the use of contact lenses, the corneal curvature is changed from prolate to oblate. In a recent observation, Singh et al studied the effect of these orthokeratology lenses on 15 eyes. At the end of four months, a mean 1.2 D of corneal flattening was observed. Moreover, the authors also reported that such users did not have any impact on the contrast sensitivity, endothelial count, axial length, and tear film parameters.<sup>109</sup> In another prospective study on young myopes, these views were supported with favorable outcomes in 25 myopic subjects.<sup>110</sup> Overall, the contact lens combined with other measures seems promising, but the cost and hygiene-related concerns need to be addressed before widespread suggestions are made.<sup>111</sup>

### Role of Atropine in Controlling the Progression of Myopia

Atropine eye drops are another mode of therapy for myopia progression mitigation, which is being experimented and being practiced since the last decade. The initial atropine study (ATOM 1) showed the effectiveness of atropine 1% eye drops for myopia progression mitigation, and subsequently, the ATOM 2 study demonstrated comparable efficacy with lower concentrations of atropine, 0.5% 0.1% and 0.01%.<sup>112,113</sup> Indian authors have also evaluated the role of atropine eye drops in myopia. In 2017, Kothari et al evaluated the role of atropine 1% eye drops and noted a reduction in myopia progression from  $-0.6\text{D}/\text{year}$  to  $-0.2\text{D}/\text{year}$  at the end of 1-year therapy.<sup>114</sup> Apart from this, the authors also stated better effectiveness of atropine, if applied during daytime.<sup>114</sup> In a multicentric randomized control trial, Saxena et al have found a beneficial role of 0.01% atropine drops in preventing progression of myopia in Indian school-going children aged 6–14 years.<sup>115</sup> Similar to ATOM 2 study findings, they also found that the use of atropine caused a minimal effect on axial length elongation. The Indian myopic scenario is different from the rest of the Asia, which is due to various reasons (many are still unidentified). Hence, more detailed studies with a larger sample size are necessary. Meanwhile, apart from the routine itching and dermatitis-related concerns due to atropine usage, the other untoward events, even though rare, must also be kept in mind.<sup>116,117</sup>

### Refractive Surgery

Besides, contact lenses, refractive surgeries are the other popular and significant modes of visual rehabilitation in myopic eyes. Various observations have been conducted to predict the outcome of these surgeries on visual quality.

### Corneal Surgical Interventions

The corneal interventions include photorefractive keratectomy (PRK), laser in situ keratomileusis (LASIK) and the femtosecond laser-assisted small incision lenticule extraction (SMILE) procedure. These do not cure myopia, but they only help in focusing the light rays without the need for an additional optical supplement like glasses. In Indian myopic eyes, an equal efficacy between wavefront-optimized and topography-guided customized ablation has been observed.<sup>118</sup> Similarly, to prevent flap-related complications of LASIK, flapless procedures like SMILE and PRK have been compared and have found comparable results (even though differences existed in higher-order aberrations).<sup>119</sup>

### Posterior Chamber/Phakic Intraocular Lens-Based Interventions

In cases where corneal-based interventions are not viable, the intraocular lens-based procedures are followed, and in recent times, these interventions are also on the rise. The phakic intraocular lens implantation has several advantages over kerato-refractive procedures, including a lower incidence of higher-order aberrations, less retinal image changes, reversibility of the procedure and better contrast sensitivity. In general, Implantable Collamer Lenses (ICL) have been noted to be safe and effective in long-term management of moderate to high myopia.<sup>120,121</sup>

In 2012, Titiyal et al studied the role of iris-fixated intraocular lenses in 85 moderate to high myopic eyes. At the end of 4 years, the refractive outcomes were stated to be fairly predictable.<sup>122</sup> Since then, several authors have evaluated the ICL as well as the Implantable phakic contact lenses (IPCL) in various circumstances and have observed promising results with both the variants. In addition, with Indian lenses, the economic feasibility and as an alternate treatment option has been highlighted including safety concerns.<sup>123–125</sup>

### Alternate Therapies for Myopia

#### Yoga and Bates's Eyes Exercises

In India, based on the evidence, various ocular exercises have been advised to improve the overall health of the eyes (Trataka Yoga, Kriya, Bates exercises and others). The near to far shifting, palming, solarization, eyewash, eye-squeezing, eye circles, eye massage and other exercises are advised. These exercises are said to act by relaxing the ocular tissues and improving their circulation. Few authors have tested these exercises on myopic eyes, and they have discovered variable or less significant evidences. As of now, the evidence is very sparse; therefore, critical thinking and future explorations are necessary to check if these modes have any effect on myopic progression.<sup>126–129</sup>

## Limitations

The current review inherits the following limitations.

- The homogeneity among studies to state the prevalence in uniform terms was lacking. Hence, this considerably hampered the representation of many results.
- The heterogeneity of population made any assessment or results applicable more accurately only to the local region where it has been undertaken.
- The current social and smart technologies have seemed to become a bane rather than a boon in some respects.
- In all sectors of myopia, larger sample size studies were lacking.

## Conclusions

To conclude, myopia in India and its understandings are evolving. The diverse nature of the country has differing prevalence rates, and the technological advancement has unequivocally added many novel insights including its genetics, imaging, morbidities, and management. However, due to lack of public awareness, social stigmatization, bullying, and lack of personal care the intended goals have not been achieved yet. Therefore, future research and policies need to be undertaken to address the existing limitations with novel concepts so that the future crisis can be handled better.

## Future Direction

Myopia is an emerging major public health problem globally as well as in India. It needs to be tackled in time with adequate preventive and curative measures, to minimize its impact in every aspect of life. Various encouraging steps have been taken; however, these tasks need further push to achieve the desired goals. The future directives for the same are as follows.

- Prospective cohort-based studies are necessary to understand the natural history, progression, genetic influences, regional differences, and various effects of interventional measures. In addition, standardized methodology including case definition, sampling strategy and measurement protocols are to be followed to prevent potential bias.

- Considering the influence of the internet, social media and television media in India, sensitization of the public and the target adolescents is the need of the hour now.
- Peer bullying and social stigmatization needs to be addressed with appropriate measures so as to prevent unnecessary psychological stress among the subjects.
- Indigenous innovations including smartphone technology and artificial intelligence need to be harnessed for various screening programs, education, and reminders.
- The addictive nature of smartphone usage and their possible adverse ocular effect in certain vulnerable groups also need to be emphasized.
- Urbanization is a need as well as a risk factor for myopia in India in future. It is difficult to convey solutions to both in one statement, hence future observations and regular assessments are necessary to have a dynamic approach.
- Future policies on myopia in India must be framed based on studies in India with the world picture as a guide.

## Disclosure

The authors report no conflicts of interest for this work.

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