Introduction

Loss of accommodative amplitude due to aging is known as presbyopia. Symptoms include diminution of vision for near sight, headache, asthenopia, and eye strain.

Many plausible mechanisms in the form of theories have been proposed for accommodation (Fig. 14.1).

Helmholtz Theory\textsuperscript{1,2}

It proposes that when the ciliary body is relaxed, the zonules are stretched, which lead to flattening of anterior lens capsule and decrease in the diameter (AP) of the lens. As opposed to when the ciliary body contracts, zonules are slackened; due to lens capsule elasticity, the anterior capsule steepens, which causes an increase in lens diameter (AP). Thus, it proposes loss of lens capsule elasticity as the main cause of loss of accommodation.

Schachar Theory\textsuperscript{3}

It proposes that during ciliary contraction, the tension in equatorial zonular fibers increases, which leads to steepening of anterior lens capsule. With aging, the distance between ciliary body and the equatorial lens capsule decreases, which causes ineffective tension generation. Most of the scleral-based interventions are based on this theory.

Catenary Theory

It proposes ciliary body, zonules, lens, and anterior vitreous, as a part of diaphragm. Contraction of ciliary body causes

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**Fig. 14.1** Illustration depicting various mechanisms of accommodation.
increase in vitreous pressure, which leads to anterior shift of lens and, thus, accommodation.

What Happens with Age?

The reason for the age-related decline in the amplitude of accommodation is not fully understood. Evidence suggests ciliary muscle atrophy and increase in connective tissue over time may lead to ciliary muscle weakening.4,5

In addition to this, lens becomes thicker and stiffer with age, which may contribute to reduced accommodation.6

Nonsurgical Methods for Correction of Presbyopia

Although in this chapter, our main focus is on the surgical correction methods of presbyopia, there is also a brief overview of more conventional methods in this section.

Spectacles

They come in a variety of designs and materials. A person can use different sets for near and distance vision. If this is tedious, near vision can be incorporated over the distance correction in the same pair of glasses.

The drawback being that it does not account for intermediate vision. To account for this problem, many designs have come up. Bifocal, trifocal, and progressive are few of the commonly used designs (Fig. 14.2). In the latter category, there can be hard progression or soft progression, depending on the refractive error and near add transition. In cases of hard progression, there is a significant complaint of image jump, which patients have great difficulty in adapting to.

Also micromonovision can be used with spectacles to varying success.

Fig. 14.2 A monofocal lens B, C, D. Bifocal lens—C-shaped, D-shaped, and executive bifocal lens C. Trifocal lens D. Progressive lens.
Contact Lens

Contact lenses can be used in many different ways to help with the problem of presbyopia:

Monovision

It is the method most commonly resorted to. Dominant eye is corrected for distance and nondominant eye for near vision. Acceptance rate is generally good. Optimum addition is generally + 1.5D. Addition more than this may cause difficulty in stereopsis and less than this may not solve the purpose of near add altogether.

Multifocal Contact Lenses

Soft bifocal or multifocal contact lenses are available in different designs (center distance/center near; two rings/multiple rings; Fig. 14.3). It has varying acceptance rates among patients. It is a pupil dependent method. The main problems associated with these designs are induction of aberrations, reduced contrast sensitivity, glare, halos, etc.

Modified micromonovision can be used with the multifocal lenses, in which one eye can be corrected for distance, and the other eye can have multifocal multifocal near add. Also, simultaneous multifocal contact lenses in both eyes can be used either with same design (center distance or center near) or crossover designs. Crossover designs may have a little more success as compared with the former.

There is a limited research that has been conducted on rigid gas permeable (RGP) lenses with multifocality. The diffractive component can be added in those to increase the range of focus.

Recent literature reports use of contact lens with pinhole. Near vision and intermediate vision improves with no negative effect on binocular visual field and distance visual acuity; although, contrast sensitivity decreases at certain frequencies.

Surgical Methods for Correction of Presbyopia

On the Basis of Cornea

Inlays

Various corneal inlays have been used for correction of presbyopia (Fig. 14.4). Below are few which are commonly used.

Kamra Inlay

It is a Food and Drugs Administration (FDA)–improved corneal implant. It is an opaque implant inserted in the corneal pocket created using femtosecond laser technology (depth of 200 μm). It is generally inserted in the nondominant eye. This polyvinylidene fluoride inlay has around 8400 micro pinholes which lead to adequate perfusion anterior and posterior to the inlay. It increases the depth of focus with minimal effect on the distance visual acuity. It works on the principle of pinhole effect and causes increase in depth of focus. It can be used with simultaneous laser-assisted in-situ keratomileusis (LASIK) surgery as well and can be implanted in nondominant eye. The main side effects are glare, halos, difficulty in subsequent cataract surgery, and LASIK flap- and
pocket-related complications (vascularization and epithelial ingrowth). Keratitis has also been reported. In cases with unsatisfactory results, the inlay can be explanted. It should be avoided in patients who require night time driving.

The results have been very encouraging with good gain in near vision and good patient satisfaction. On long-term follow-up as well, the vision remained stable with no significant change in refractive errors.

**Flexivue Inlay**

It is a hydrophilic acrylic polymer implant with an overall diameter of 3.2 mm. It has a central disk with no power, which provides for distance vision and surrounding that are multiple rings of increasing power providing multifocality. It is a transparent inlay. It has a central hole which provides nutrition through diffusion. It is currently under FDA trials.

**Rain Drop Inlay**

It is a corneal reshaping inlay with no power of its own. It was FDA-approved in 2016 but has been recalled due to significant corneal haze in postoperative period. Due to this haze, there is an increasing number of inlay removals that are being performed. This implant is no longer recommended for presbyopia correction.

**Icolens**

It is the most recent addition to the inlay family. It is made up of hydrophilic acrylic hydrogel. It is very similar to flexivue inlay and is under FDA trials.

**Small Incision Lenticule Extraction Lenticule**

Animal study on primates shows good results for presbyopia correction using small incision lenticule extraction (SMILE) lenticule. Central cornea steepens and shape becomes prolate. There is no postoperative corneal haze at 6 months. The drawbacks include thinning of the lenticule in the postoperative period, with regression after a few months. There is also theoretical risk of rejection of the lenticule by the host body.

Jacob et al reported using SMILE lenticule for presbyopia in four patients with good visual outcome. All the patients had good near vision (J2), decent intermediate vision, and good distance visual acuity. There was no gross ocular discomfort, glare, halos, or rejection.
Laser Vision Correction

PresbyLASIK

Correction of presbyopia at the corneal plane by creating a multifocal ablation profile using excimer laser is achieved by a procedure known as PresbyLASIK. It can be of two types:

1. **Central PresbyLASIK**: It is achieved by creating a hyperpositive area in the central cornea which helps in near vision; the peripheral area is left for distance vision. As miosis occurs during the near vision triad, this approach seems very practical, as the central area is left for near vision. It can be used in hyperopes, myopes, and emmetropes. The drawback being the centration of the ablated area over the visual axis, which can often be unsatisfactory, as more often than not, the pupillary axis does not coincide with the visual axis.

   Alio et al reported the outcomes with 72% of the 25 eyes having uncorrected near visual acuity (UNVA) better than 20/40. Contrast sensitivities decreased uniformly.\(^{14}\)

2. **Peripheral PresbyLASIK**: In this procedure, a negative spherical aberration is induced in the peripheral cornea. Thus, the peripheral cornea is utilized for near vision and the central cornea is used for distance vision (Fig. 14.5). This procedure is mainly used for hyperopes. In myopic patients, this procedure is at a disadvantage in that it leads to excessive loss of corneal tissue due to myopia correction in central cornea.

   Epstein et al reported 92% and 89% of spectacle independence in myopic and hyperopic patients at 1-year follow-up. Higher order aberrations (HOAs) were increased in both the groups.\(^{15}\)

**Supracor**

It is an algorithm developed by Technolas Perfect Vision GmbH, Munich, Germany. It optimizes aberrations while creating a hyperpositive area in the central 3 mm of cornea (+ 2 near add; Fig. 14.6). It can be treated in a symmetrical or asymmetrical manner. In the former, both the eyes are treated for near vision. In the latter, the dominant eye is treated for distance (plano) and the nondominant eye is treated for near.

   Ryan et al reported that binocular UNVA better than 0.2 logMar in 91% of the patients undergoing hyperopic presbyopic LASIK (Supracor). HOAs were increased but there was no significant increase in trefoil and coma.\(^{16}\) The majority (96%) of patients were happy with the procedure in this study.

**PresbyMax**

PresbyMAX (SCHWIND eye-tech-solutions GmbH, Kleinostheim, Germany) biaspheric corneal surface is

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![Image](https://via.placeholder.com/150)

**Fig. 14.5** Illustration showing ablation pattern in peripheral PresbyLASIK. Abbreviation: LASIK, laser in-situ keratomileusis.
Presbyopia Correction

created and multifocality is achieved by creating a hyper-
positive area from +0.75D to +2.50D. The area peripheral to
this area is ablated for distance vision.

Uthoff\(^1\) reported good visual outcomes with 90% of
emmetropic patients and 80% of the myopic and hyperopic
patients having UNVA better than 0.3logRAD.

Luger\(^1\) reported 84% of all the patients treated using
PresbyMax had UNVA of 0.1logRAD or better.

**Laser-blended Vision**

Presbyond Laser Blended Vision (Carl Zeiss Meditec, Jena,
Germany) is a type of monovision in which the dominant
eye is corrected for distance and the nondominant eye is
corrected for near (around 1.5D; Fig. 14.7). It is a refined
version, with the refinement being that it is a wavefront-
optimized ablation which leads to low aberration profile.

Preoperative workup includes:

- Best-corrected near visual acuity (BCVA) and pupillary
  reactions.
- Manifest refraction.
- Dominance test (hole test, finger pointing test, camera
  test, and rifle shooting test).
- Tolerance test (to test for cross blur).
- Schirmer’s test and tear film breakup time (TBUT; more
  chances of dry eye in adults).
- Corneal topography, tomography, and corneal biome-
  mechanics (ocular response analyzer).

Postoperatively, there are three stages of recovery which
overlap between swelling, healing, and adaptation. The
adaptation part can take up to 3 to 4 months.

It was reported that in emmetropic, myopic, and astig-
matic patients, 96% achieved vision better than J2 (Jaeger
scores).\(^1\)\(^9\),\(^2\)\(^0\) In hyperopic patients, only 81% achieved near
vision of J3 or better.\(^2\)\(^1\)

**Conductive Keratoplasty**

It is based on the premise that heat denatures collagen.
Eight spots are placed circumferentially at 6 mm, 7 mm,
and 8 mm from the center of optical zone. Thus, when the
collagen denatures, it contracts and flattens the cornea in
the center. Stahl et al\(^2\)\(^2\) reported that after 1-year follow-up,
patients had good near vision. The vision improved from J10
to J1. There were no complaints of postoperative discomfort
as well.

However, the major drawback is the regression overtime
with this procedure and majority of the patients returning
to their baseline error. Due to this reason conductive kerato-
plasty is not extensively in use currently.

**On the Basis of Intraocular Lenses**

**Phakic Multifocal IOLs**

There is limited literature on use of phakic multifocal
intraocular lenses (IOLs) in presbyopia correction.
They can be angle-supported or implantable collamer lenses (ICLs). The angle-supported IOL has haptic of polymethylmethacrylate (PMMA) material and optic of hydrophilic acrylic material. It has a four-point fixation. With this, IOL results were satisfactory but inferior to refractive IOLs. Complication rate was low. But in patients with slight lens opalescence, there was marked reduction in visual acuity.

The other type of phakic IOL for presbyopia is implantable collamer lens with central hole. Due to the presence of central hole, iridotomy is not needed to prevent pupillary block and the chances of development of cataract are low. Preoperative workup has to be done properly with anterior chamber (AC) depth of a minimum of 3 mm. It is tried as a monovision therapy. The postoperative results are satisfactory with reduction in spectacle dependence and good vision in near and intermediate distance.

**Refractive Lens Exchange/Multifocal IOLs**

This approach is the most widespread and accepted treatment modality for presbyopia. Multifocal IOLs has passed through generation of modifications to reach the present level and there is still ongoing research to improve and refine it even further.

Initially, they used to be refractive in nature with multiple rings of refraction. The center of the IOL can either be for near or distance. The refractive multifocal IOL is pupil-dependent and patients may have complaints of glare, halos, and loss of contrast sensitivity.

Recent designs use diffractive designs. They have two foci. One for near and one for distance. The diffractive steps are added on to the anterior or posterior surface to provide for the near focus. The distance between the steps determine the power of add and height of the steps.
Presbyopia Correction

Fig. 14.8 Diffraction steps (L) and apodization (R).

determine the division of amount of light diffracted to near and distance foci. Some IOLs have an apodised design of diffraction steps, which means that the height of the steps decreases toward the periphery. So, in mesopic conditions, when more of diffraction rings are exposed, more of the light is focused for distance rather than near. This, in turn, leads to a drawback: in dim lit situations, it is difficult to work for near with multifocal IOLs.

More recently, trifocal lenses which provide focus for intermediate distance as well have been developed with good success rates.

The most recently FDA-approved IOL is a type of extended range of vision or extended depth of focus. It has an echelette type of design. It has nine echelettes at the back of the IOL which are not exactly perpendicular but slightly angled. The slight angulation leads to extended focus for intermediate visual acuity rather than two foci for near and distance as in most multifocal IOLs (Fig. 14.9). Although, the complaints of glare and halos drastically decrease with this IOL but it is not altogether eliminated. Although patients are to be counseled about need of glasses for near vision, they will have good vision for most of the intermediate range of vision and distance vision. Chromatic aberrations are also very less with this type of IOL. Also, patient has to be counseled about a period of neuroadaptation that is required after implantation of this IOL.

The most important criteria in successful multifocal IOL implantation is patient selection.

Pseudophakic Monovision

With increasing demand of spectacle independence and affordability, a considerable issue (especially in developing countries), pseudophakic monovision is a very viable option. It can be achieved by using conventional method, crossover method, and hybrid method. In conventional method, the dominant eye is corrected for plano, and the nondominant eye is corrected for myopia and vice versa in crossover design. Generally, for successful monovision, −1.5D is an acceptable myopia in the nondominant eye. For minimonovision, dominant eye is implanted with monofocal IOL for emmetropia. Nondominant eye is implanted with the aim of residual myopia of around −0.75D. In hybrid monovision, dominant eye is implanted with monofocal IOL and nondominant eye is implanted with multifocal IOL. It is especially useful for people younger than 60 years.

Studies have reported that spectacle independence with monovision was comparable with multifocal IOLs. However, multifocal IOLs are generally superior in this respect. Reading ability may be better with this approach as compared with multifocals. Contrast sensitivity is better as compared with multifocal IOLs. Also, night time problems of glare and halos are a little less with this approach. Drawbacks are poor stereoacuity and low-clarity in near and intermediate vision as compared with multifocal IOLs.

Accomodating IOLs

Although accommodating IOLs are not used in our setup, this chapter wouldn’t be complete without their mention. These IOLs are based on the premise of changing their shape in response to ciliary body contraction, contraction of lens bag, and positive vitreous pressure. Crystalens and Trulign toric IOL are the only two accommodating IOLs approved by FDA. Crystalens, Tetraflex, and IO human optics are the most commonly used accommodating IOLs. They are all single optic. They have good visual outcomes; however, bag contraction with loss of accommodating ability of the IOL is very common.
Other IOLs in development on the same lines are Nu lens and bag filling technology. These are still under research.

On the Basis of Sclera

The scleral approaches are based on the premise of Schachar theory of accommodation. According to Schachar, due to aging, the lens grows in equatorial diameter, which leads to decrease in distance between lens equator and ciliary body. The decreased distance leads to inadequate pull on zonules which, in turn, leads to inadequate zonular tension and consequent loss of accommodation. The decrease in distance has been proven on magnetic resonance imaging (MRI). The extraocular approaches are considered safer, as they don’t have decrease in distance vision, loss of contrast, halos, glare, etc.

On the above-stated premise, LaserACE (Ace Vision Group, Silver Lake, Ohio, USA) and VisAbility Implant System Surgery Scleral Implants (Refocus Group, Dallas, Texas, USA) were developed and are still under trials for actual mechanism of action and efficacy.

Laser Assisted Presbyopia Corrections\textsuperscript{25,26}

The LaserACE system uses erbium-yag laser. They use 600 μm spot size. Nine spots in a diamond matrix pattern are ablated using fiber optic hand piece in nine oblique quadrants of the eye. The postulated mechanism is that it decreases the scleral rigidity and reduces the distance between scleral spur and ora serrata. The latter helps in restoring the anatomical relation of the accommodating mechanism. Preliminary reports are encouraging with improvement in near vision and good patient satisfaction.

Scleral Implant-based Approach

It is based on the concept that if the distance between ciliary body and the lens equator is increased by pulling the sclera outward in an area of the ciliary body, effective tension on zonules can be increased. Thus, VisAbility Implant System Surgery Scleral Implants\textsuperscript{27} (Refocus Group, Dallas, Texas, USA) are rice grain-sized implants which are placed
in scleral tunnels 4 mm from limbus. The procedure requires 360 degrees conjunctival peritomy and formation of scleral tunnels. Preliminary results of the trial show improvement in near vision but prolonged ocular surface recovery.

**Conclusion**

In the current era, various modalities are available for correction of presbyopia. A cornea based or lens based approach may be used based on the age, requirement, amount of refractive error and nucleus status. Monovision using corneal procedure or lens based procedure is a fairly common procedure with low cost and good outcomes. In older patients requiring permanent correction, multifocal IOLs may provide a more suitable alternate. Hence, consideration of variety of patient and surgery related factors can help in achieving excellent outcomes.

**References**


27. U.S. National Institutes of Health Clinical Trials. A Clinical Trial of The VisAbility Micro Insert System for Presbyopic Patients