Contact Lens and Anterior Eye xxx (xxxx) xxx

Contents lists available at ScienceDirect

Contact Lens and Anterior Eye

journal homepage: www.elsevier.com/locate/clae

Review Article

Contact lenses for visual rehabilitation in post-keratoplasty eyes: A systematic review

Sina Khosravi Mirzaei [a,b,1], Sepehr Feizi [b,1], Fatemeh Hatami [c], Firouze Hatami [a,b,*], Seyed Mohamadmehdi Moshtaghion [d]

[a] Ophthalmic Research Center, Research Institute for Ophthalmology and Vision Science, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[b] Ocular Tissue Engineering Research Center, Research Institute for Ophthalmology and Vision Science, Shahid Beheshti University of Medical Sciences, Tehran, Iran
[c] Student Research Committee, Lorestan University of Medical Sciences, Khorramabad, Iran
[d] Department of Regeneration and Cell Therapy, Andalusian Molecular Biology and Regenerative Medicine Centre (CABIMER), Avda. Américo Vespucio 24, 41092 Seville, Spain

ARTICLE INFO

Keywords:
Corneal transplantation
Contact lens
Visual acuity
Daily wearing duration
Subjective comfort
Discontinuation
Complications

ABSTRACT

Purpose: To evaluate the role of contact lenses (CLs) in visual rehabilitation following keratoplasty.
Methods: Four databases, including PubMed, Scopus, Web of Science, and Embase were systematically searched for studies published between January 2010 and July 2023. Visual outcomes, daily wearing duration, subjective comfort, rate and etiology of CL discontinuation, corneal endothelial cell density, central corneal thickness, and complications were extracted.
Results: This review included thirteen case series and two chart reviews, analyzing a total of 464 eyes, of which 97% underwent penetrating keratoplasty. Scleral CLs were the most frequently fitted lens (285 eyes, 61%). All studies reported a significant improvement in visual acuity with CL correction. Most post-keratoplasty patients could wear CLs comfortably for 8 to 12 h/day. The rate of CL dropout ranged from 0% to 39%, mainly due to CL intolerance, discomfort, and graft rejection. Corneal graft rejection (18 eyes), conjunctival hyperemia (8 eyes), corneal epithelial trauma (5 eyes), graft edema (4 eyes), and microbial keratitis (3 eyes) were the most frequently reported complications.
Conclusion: CLs are effective for improving visual acuity following keratoplasty, with minor complications depending on the type of CL.

1. Introduction

Keratoplasty is a surgical procedure used to treat a wide range of corneal disorders, including corneal ectasia, dystrophies, opacities, and scars [1–3]. Despite advances in surgical techniques, postoperative astigmatism remains the primary cause of suboptimal visual acuity after corneal transplantation [4]. Approximately 20 % of patients experience high postoperative astigmatism [4], often associated with irregularities at the corneal graft-host junction, resulting in an increase in higher-order aberrations [5,6].

The management of post-keratoplasty astigmatism and associated visual impairment includes a variety of surgical and nonsurgical approaches. Common surgical interventions for visual rehabilitation include suture tension adjustment, selective suture removal, incisional keratotomy, laser refractive surgery, implantation of intrastromal corneal ring segments, wedge resection, and repeat keratoplasty [4,7,8]. However, further surgical procedures may not be acceptable to all patients. Additionally, patients with high graft astigmatism may not achieve successful visual rehabilitation with spectacles. In these cases, contact lenses (CLs) may provide better visual outcomes [4,9]. CLs are recommended for individuals with regular astigmatism exceeding 3 diopters (D) or irregular astigmatism, where conventional spectacles fail to provide adequate optical correction [7,9,10].

Various types of CLs, including soft, rigid, hybrid, and piggyback CLs, have been used to improve visual acuity in post-keratoplasty patients [11–15]. Soft CLs are generally recommended for patients with

* Corresponding author at: Ocular Tissue Engineering Research Center, Research Institute for Ophthalmology and Vision Science, Shahid Beheshti University of Medical Sciences, Tehran, Iran.
E-mail address: firouze.hatami1376@gmail.com (F. Hatami).
[1] These two authors have equally contribution in this work.

https://doi.org/10.1016/j.clae.2025.102374
Received 6 July 2024; Received in revised form 7 January 2025; Accepted 8 January 2025

astigmatism ≤ 1 D, whereas rigid CLs with large diameters are often preferred for high or irregular astigmatism, to prevent additional pressure on the graft-host junction [4,7,13]. The overall performance of different CL types is also affected by patient compliance and tolerance. Currently, no systematic reviews have considered the efficacy and safety of CLs for visual rehabilitation following keratoplasty. Therefore, this review integrated the results of various studies to examine the role of CLs in the management of refractive errors after keratoplasty.

2. Methods

2.1. Study selection

The article selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol [16]. The inclusion criteria were as follows: 1) studies that investigated the role of CLs in visual rehabilitation in post-keratoplasty patients, 2) experimental studies, case series, observational studies, and clinical trials, and 3) studies reporting visual acuity after CL fitting. Case reports, correspondence, conference papers, editorials, short surveys, letters, reviews, animal studies, and non-English articles were excluded. Additionally, studies including mixed populations of operated and non-operated patients, without separate reporting of visual outcomes for post-keratoplasty patients, were excluded.

2.2. Literature search

A comprehensive search was conducted across four databases, including PubMed, Scopus, Web of Science, and Embase, covering studies published from January 2010 to July 2023. The following terms and keywords were used to identify relevant studies: (contact lens OR soft contact OR soft lens OR mini-scleral OR semi-scleral OR scleral lens OR scleral contact OR toric contact OR toric lens OR rigid gas permeable OR rigid gas-permeable OR hybrid lens OR hybrid contact OR piggyback OR PROSE) AND (penetrating keratoplasty OR deep anterior lamellar keratoplasty OR Descemet stripping endothelial keratoplasty OR Descemet membrane endothelial keratoplasty OR keratoplasty OR corneal graft OR corneal grafting OR cornea transplant OR corneal transplantation). Due to recent changes in the terminology used to describe rigid contact lenses, an additional search was conducted using the following keywords: corneal rigid lens, scleral lens, and corneoscleral lens. Corneal rigid lenses refer to rigid CLs that bear only on the cornea. Corneoscleral lenses refer to CLs that bear on both the cornea and sclera. Scleral lenses refer to CLs that are fully supported by the sclera and vault the cornea and limbus [17]. Supplementary Table S1 provides detailed search strategies for each database.

2.3. Data extraction and outcome measures

The relevant articles identified through the literature search were imported into EndNote software. Title and abstract screening were independently performed by two reviewers (S.K.M. and F.H.), and any disagreements were resolved through discussion or consultation with a third reviewer (S.F.). The full texts of all potentially eligible articles were retrieved for data extraction. The extracted information included the name of the first author, year of publication, study design, sample size, eligibility criteria, type of transplant, type of CL, mean time interval between keratoplasty and CL fitting, mean lens diameter, lens power, and follow-up duration. The primary outcome was the improvement in visual acuity after visual rehabilitation with CLs. Secondary outcomes included daily wearing duration, subjective comfort, rate and etiology of CL discontinuation, corneal endothelial cell density, central corneal thickness, and complications.

2.4. Quality assessment

The methodological quality of each study was assessed based on its design, using the Case Series Critical Appraisal Tool for case series [18] and the Newcastle-Ottawa Scale for cohort chart review studies [19]. Two independent authors (S.K.M. and F.H.) evaluated the quality of the eligible studies, with any disagreements resolved by a third author (S.F.).

3. Results

3.1. Study selection

The detailed flowchart of the selection process is presented in Fig. 1. The initial search identified 2748 publications, of which 624 duplicates were removed. Following the review of titles and abstracts, 1892 articles were excluded. Subsequently, full-text screening led to the exclusion of 9 studies. Finally, 15 articles met the criteria for inclusion in this systematic review [20–34].

3.2. Characteristics of studies

The characteristics of eligible studies are summarized in Table 2. Thirteen case series and two cohort chart reviews were included. The sample sizes of the studies varied from 9 to 56 eyes, comprising a total of 464 eyes. The studies were conducted in the USA [21,22,25], Israel [20,23], India [29,30], Turkey [28,33], Iran [24], France [32], Spain [31], the Netherlands [27], China [34], and Brazil [26]. The mean participant age ranged from 30 to 69.5 years; however, one study provided only an age range of 16 to 77 years [20]. All included studies involved patients who underwent penetrating keratoplasty (PK; 450 eyes). Additionally, two studies included patients who underwent deep anterior lamellar keratoplasty (DALK; 13 eyes) [24,27], with one study also including a rotational graft [24]. Six studies included non-operated patients with other corneal ectasia in addition to post-keratoplasty patients [20,21,27,29,30,32].

The mean interval between keratoplasty and CL fitting was 1 to 12.2 years. The types of CLs fitted varied among the studies, including scleral CLs (285 eyes) [20,21,23,25,30,32,33], corneoscleral CLs (108 eyes) [24,26,29,31], corneal rigid CLs (49 eyes) [22,34], hybrid CLs (21 eyes) [28], and soft CLs (1 eye) [27]. One study compared bitoric and spherical corneal rigid CLs [22]. Another study reported the outcomes associated with the fitting of soft, rigid, and hybrid CLs following corneal transplantation [27]; however, no study directly compared different types of CLs. The mean follow-up period after lens fitting varied from 1 month to 5.2 years.

3.3. Quality assessment

The quality assessment of the included case series is presented in Table 1. Of the 13 case series evaluated, 11 studies were rated as high quality (≥ 7 out of 10 “yes” responses) [20,23–28,30,31,33,34], and two studies were rated as low quality (< 7 out of 10 “yes” responses) [29,32]. The cohort chart review studies were judged to be of good quality, achieving 7 out of 9 stars [21,22].

3.4. Outcomes

The outcome measures are detailed in Table 3.

3.4.1. Visual acuity

All included studies demonstrated that contact lens-corrected visual acuity (CLCVA) was better than uncorrected visual acuity (UCVA) and habitual best-corrected visual acuity (BCVA). Severinsky et al. [23] reported a significant improvement in visual acuity with scleral CLs compared to habitual BCVA (0.78 ± 0.25 versus 0.30 ± 0.18 [decimal

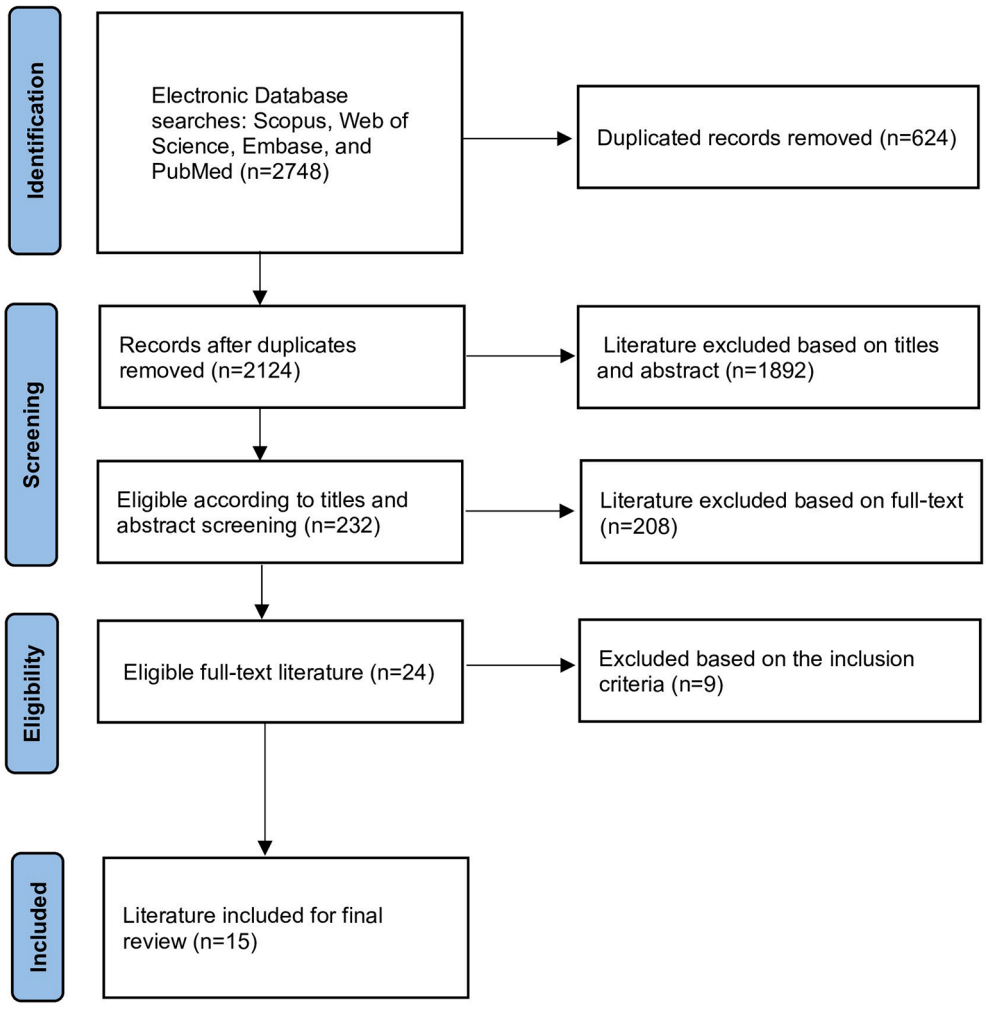

Fig. 1. PRISMA flowchart for eligible literature.

Table 1
The case series critical appraisal tool by the Joanna Briggs Institute.

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	% of Yes
Severinsky et al 2010	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Unclear	No	Yes	70 %
Severinsky et al 2014	Yes	Yes	Yes	Yes	Unclear	Yes	Yes	Yes	No	Yes	80 %
Alipour et al 2015	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	90 %
Barnett et al 2016	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	90 %
Rocha et al 2017	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	90 %
Visser et al 2016	Yes	Yes	No	Yes	Yes	Yes	Yes	Yes	No	Yes	80 %
Altay et al 2018	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	90 %
Kumar et al 2019	Yes	Yes	Yes	No	Unclear	Unclear	Unclear	Unclear	No	Yes	40 %
Kumar et al 2019	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	90 %
Montalt et al 2020	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	80 %
Penbe et al 2021	Yes	Yes	Yes	No	Yes	Yes	Yes	Yes	No	Yes	80 %
Navel et al 2021	Yes	Yes	Yes	Yes	Yes	No	No	No	No	Yes	60 %
Zhang et al 2023	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes	No	Yes	80 %

format], respectively, $P < 0.0001$), with a gain of ≥ 2 lines in 31 eyes (94 %). In another study, the mean BCVA achieved with spectacles was 20/50, whereas with scleral CLs, it improved to 20/25 [25]. Notably, 58.3 % of patients experienced an improvement in visual acuity with scleral CLs, and 31.3 % achieved a visual acuity equivalent to their habitual BCVA [25]. Visser et al. [27] reported a significant improvement in visual acuity after fitting scleral CLs (0.42 logMAR before versus 0.05 logMAR after CL fit, $P < 0.001$). Similarly, Navel et al. [32] found significantly superior visual acuity while wearing scleral CLs in comparison to spectacle-corrected visual acuity (0.18 ± 0.27 logMAR versus 0.59 ± 0.50 logMAR, respectively, $P < 0.001$). Kumar et al. [30] reported that scleral CLs improved visual acuity (median, 0.22 logMAR) compared with UCVA (median, 1.10 logMAR) and spectacle-corrected visual acuity (median, 0.65 logMAR). Lee et al. [21] found an increase in visual acuity by 0.85 logMAR after fitting scleral CLs, from 1.18 ± 0.77 to 0.32 ± 0.61 logMAR ($P < 0.0001$). Penbe et al. [33] reported that UCVA and BCVA were 1.15 ± 0.26 and 0.84 ± 0.24 logMAR, respectively, which improved to 0.13 ± 0.09 logMAR after scleral CL fitting. In this study, all post-keratoplasty eyes had better visual acuity with scleral CLs compared to habitual BCVA [33]. A CLCVA of $\geq$ 20/40

Table 2
Characteristics of the included studies.

Author, Date	Country	Design	Eyes (Patients)	Age (mean ± SD), years	Eligibility criteria	Type of transplant	Type of contact lens	Follow up period ± SD	Lens diameter, mm	Lens power, diopters	Mean time interval between keratoplasty and lens fitting
Severinsky et al., 2010 [20]	Israel	Retrospective case series	39 (–)	Range: 16–77 *	–Extreme corneal irregularities –high astigmatism	PK	Scleral	27.5 months *	18.5	_	_
Lee et al., 2013 [21]	USA	Retrospective chart review	23 (18)	69.5	–History of keratoplasty –Failing conventional therapies for visual rehabilitation	PK	Scleral	_	_	_	_
Phan et al., 2014 [22]	USA	Retrospective chart review	Bitoric RGP: 14 (14) spherical RGP: 14 (14)	Bitoric RGP: 61.3 ± 12.6 spherical RGP: 61.1 ± 10.7	–Use of RGP for 4 months or more	PK	Bitoric RGP vs spherical RGP	4 months	Bitoric RGP:9 – 11.4 Spherical RGP: 10.6 – 11.2	_	_
Severinsky et al., 2014 [23]	Israel	Retrospective case series	33 (28) Group A, grafts with < 20 years (18 eyes) Group B, grafts with ≥ 20 years (15 eyes)	43.0 ± 14.2	–Unacceptable visual acuity with spectacles, corneal rigid or soft CLs –Corneal rigid or soft CLs contraindication –Other surgical options were undesirable –Using scleral CLs for three or more years	PK	Scleral	5.2 ± 2.2 years	18.50 – 19.00	_	12.2 ± 10.7 years
Alipour et al., 2015 [24]	Iran	Prospective case series	56 (45)	34.6 ± 10.9	–Unacceptable visual acuity with spectacles –Unable to fit corneal rigid CLs	PK (43 eyes) DALK (12 eyes) Rotational graft (1 eye)	Corneoscleral	21.92 ± 6.8 months	15.8	Mean ± SD: −6.93 ± 4.82 (−21.00 – +2.00)	–
Barnett et al., 2016 [25]	USA	Retrospective case series	48 (34)	59.0 ± 18.6	–History of keratoplasty	PK	Scleral	27.2 ± 14.8 months	mean: 16.6 (15.6 –18.4)	_	9.2 ± 9.6 years
Rocha et al.,2017 [26]	Brazil	Retrospective case series	27 (21) Group A, grafts with < 10 years (14 eyes) Group B, grafts with ≥ 10 years (13 eyes)	42.3 ± 13.1	–History of PK –Insufficiently corrected –Visual acuity with spectacles –Inability to tolerate or achieve better results with other contact lens models	PK	Corneoscleral	≥6 months (20 eyes) < 6 months (7 eyes)	16.0 (10 eyes) 16.5 (5 eyes) 17.5 (10 eyes) 18.2 (2 eyes)	_	10.6 ± 7.3 years
Visser et al., 2016 [27]	The Netherlands	Prospective case series	55 (55)	63	–More than 18 years old and use of CL for 3 months or more	PK (54 eyes) DALK (1 eye)	Scleral (51 eyes) Soft (1 eye) Corneal rigid (2 eyes)	≥3 months	15 to 18 or 18 to 22	_	_

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Table 2 (*continued*)

Author, Date	Country	Design	Eyes (Patients)	Age (mean ± SD), years	Eligibility criteria	Type of transplant	Type of contact lens	Follow up period ± SD	Lens diameter, mm	Lens power, diopters	Mean time interval between keratoplasty and lens fitting
Altay et al., 2018 [28]	Turkey	Prospective case series	20 (20)	38.42 ± 4.89	−Astigmatism more than 4 diopters −Visual acuities insufficiently corrected with spectacles	PK	Hybrid (1 eye) Hybrid	4.32 ± 0.45 months	14.5	+10.00 – −20.00	19.2 ± 6.6 months
Kumar et al., 2019 [29]	India	Prospective case series	16 (−)	30 ± 5	−Visual function reduction resulting at least in part from higher-order aberrations −Not improving with conventional treatments of spectacles and soft CLs	PK	Corneoscleral	_	13.0 – 14.6 *	_	3 years
Kumar et al.,2019 [30]	India	Retrospective case series	21(−)	43.5 (median)	−History of PK	PK	Scleral	_	18.5 *	−3.1 (median)	_
Montalt et al., 2020 [31]	Spain	Prospective case series	9 (9)	44.56 ± 17.33	−Keratoconus patients who were unsatisfied with their vision with spectacles, soft CLs, or corneal rigid CLs after keratoplasty surgery rigid CLs	PK	Corneoscleral	12 months	12.60 – 14	+20.00 – –25.00	12 months
Navel et al., 2021 [32]	France	Retrospective case series	32 (20)	43.3 ± 16.3 *	−Age ≥ 18 years' old −Irregular astigmatism −Failure of corneal rigid CLs wear	PK	Scleral	22.3 ±13.8 months *	15 – 18	_	_
Penbe et al., 2021 [33]	Turkey	Prospective case series	38 (35)	36.39 ± 10.18	−More than 18 years' old −High refractive errors −Unsatisfactory visual acuity (BCVA < 20/40) with spectacles, corneal rigid CLs and soft toric contact lenses	PK	Scleral	14.25 ±1.3 months	16.5 – 17	_	36.6 ± 12.31 months
Zhang et al., 2023 [34]	China	Prospective case series	19 (19)	30.45 ± 5.83	−Sutures were removed of at least 3 months before lens fitting −Best spectacle-corrected visual acuity > 0.3 logMAR −Corneal endothelial cell count ≥ 1000/mm^2	PK	Corneal rigid	1 month	10.0 – 10.6	_	4.4 ± 2.0 years

SD: standard deviation, PK: penetrating keratoplasty, DALK: deep anterior lamellar keratoplasty.

* The information belonged to mix population group, with no separate report on post keratoplasty patients.

Table 3
Summary of findings of studies.

Author	UCVA	Habitual BCVA	CLCVA	Contact lens wearing duration (hours/ day)	Subjective comfort	Contact lens discontinuation	Complications	Comment
Severinsky et al [20]	_	(20/70) *	Achieved 20/40 or more in 92 % of cases with median BCVA of 20/ 25.	12.2 (8–16)	_	_	_	Positive fluid-venting was highly associated with longer scleral contact lens wearing time
Lee et al [21]	_	1.179 ± 0.77 LogMAR	0.321 ± 0.61 LogMAR	_	Pre-CL OSDI score: 77.25 ± 72.91 Post-CL OSDI score: 15.99 ± 8.56	_	_	_
Phan et al [22]	_	Bitoric group: 0.51 ± 0.37 LogMAR (20/65) Spherical group: 0.32 ± 0.16 LogMAR (20/41)	Bitoric RGP: 0.10 ± 0.11 LogMAR (20/25) Spherical RGP: 0.08 ± 0.12 LogMAR (20/24)	>8	_	0	Bitoric RGP: No complication Spherical RGP: −Giant papillary conjunctivitis (3 eyes, 21.4 %) −Corneal abrasion (n = 1, 7.1 %) −Superficial punctate keratitis (n = 2, 14.3 %)	No complication with bitoric RGP was probably due to its better fit on corneal grafts.
Severinsky et al [23]	_	0.30 ± 0.18	0.78 ± 0.25	11.9 ± 3.5	_	−Corneal graft decompensation (2 eyes, 6.1 %) −Graft rejection (1 eye, 3.0 %) −End stage glaucoma (1 eye, 3.0 %)	−Microbial keratitis (2 eyes, 6.1 %) −Graft rejection (10 eyes, 30.3 %) −Graft decompensation (2 eyes, 6.1 %) −Graft-host ectasia (9 eyes, 27.3 %)	_
Alipour et al [24]	1.06 ± 0.59 LogMAR	0.76 ± 0.50 LogMAR	0.17 ± 0.18 LogMAR	9.62 ± 4.5	Ideal fit (40 eyes) Acceptable (16 eyes)	5 eyes/ 4 patients −Contact lens intolerance (2 eyes of one patient) −Difficult handling (1 eye) −Economic reasons (1 eye)	−Conjunctival hyperemia (2 eyes of one patient) −Asymptomatic conjunctival folds (number not specified)	Only 19 of 45 patients ordered their lenses despite initial successful fit.
Barnett et al [25]	_	Spectacle correction: 20/50 Contact lens correction: 20/32	20/25	10< (27 eyes) 6–10 (9 eyes) <6 (12 eyes)	Comfortable (35 eyes, 72.9 %) Mostly comfortable (11 eyes, 22.9 %) Uncomfortable (2 eyes, 4.2 %)	−Difficulty with SCLs insertion or removal (8 eyes, 16.7 %) −Dissatisfaction with the vision (4 eyes, 8.3 %) −Graft rejection (3 eyes, 6.3 %) −Discomfort (2 eye, 4.2 %)	−Graft rejection (6 eyes, 12.5 %)	Subjective complaints: difficulty with lens insertion and/or removal (14 eyes), haze, blurriness, or haloes (11 eyes), excessive tear debris (11 eyes), and discomfort (3 eyes)
Rocha et al [26]	Total: 1.4 LogMAR graft with < 10 years: 1.35 LogMAR graft with > 10 years:1.45 LogMAR	Total: 0.39 ± 0.34 LogMAR graft with < 10 yr: 0.46 LogMAR graft with > 10 years: 0.3 LogMAR	Total mean: 0.09 ± 0.12 LogMAR graft with < 10 years: 0.10 ± 0.14 LogMAR graft with > 10 years: 0.07 ± 0.09 LogMAR	_	Discomfort (1 eye, 3.7 %)	−Intolerance (2 eyes, 7.4 %) −Cornealedema (2 eyes, 7.4 %)	−Corneal edema (2 eyes, 7.4 %) −Microbial keratitis (1 eye, 3.7 %)	In patient with microbial keratitis, Contact lens wear was suspended, and an appropriate topical antimicrobial agent was administered. After two weeks, he was able to resume lens wear.

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Table 3 (*continued*)

Author	UCVA	Habitual BCVA	CLCVA	Contact lens wearing duration (hours/day)	Subjective comfort	Contact lens discontinuation	Complications	Comment
Visser et al [27]	_	0.42 LogMAR (20/53)	0.05 LogMAR (20/22)	median: 15 (6–18)	The median Visual Analogue Scale score: Comfort: 84 (14–97) Visual Quality: 84 (14–96) Lens Handling: 85 (44–96) Overall Satisfaction: 85 (15–97)	_	_	_
Altay et al [28]	Median: 1.00 LogMAR	Median: 0.40 LogMAR	Median: 0.05 LogMAR	8.37 ± 1.95 (4–13)	_	−Intolerance and vault reduction and corneal contact at the transition zone (2 eyes, 10 %)	−Conjunctival hyperemia and corneal epithelial defects (2 eyes, 10 %)	No significant difference was observed in central corneal thickness before and 3 months after contact lens fitting.
Kumar et al [29]	–	0.63 ± 0.37 LogMAR,	0.07 ± 0.10 LogMAR	_	_	_	_	_
Kumar et al [30]	1.10 LogMAR (median)	0.65 LogMAR (median)	LogMAR 0.22 (median)	6 (median)	_	_	_	_
Montalt et al [31]	_	0.22 ± 0.15 LogMAR	0.02 ± 0.06 LogMAR	9.78 ± 1.9	Comfortable (5 patients, 55.6 %) Neither uncomfortable nor comfortable (3 patients, 33.3 %) Uncomfortable (1 patient, 11.1 %)	_	None	Two patients could not tolerate corneoscleral CLs in the fitting procedure. Corneal resistance factor significantly increased 1 year after CL wearing.
Navel et al [32]	_	0.59 ± 0.50 LogMAR	0.18 ± 0.27 LogMAR	10 ± 4.1 *	Comfort: 82.3 Quality of vision: 76.5 Handling: 75 Overall satisfaction: 81 *	5 eyes, 15.6 %	_	_
Penbe et al [33]	1.15 ± 0.26 logMAR	0.84 ± 0.24 LogMAR	0.13 ± 0.09 LogMAR	_	_	3 eyes:7.8 % −Excessive conjunctival hyperemia related to pinguecula (n = 1 eye:2.6 %) −Corneal graft rejection (n = 2 eyes:5.2 %)	−Excessive conjunctival hyperemia related to pinguecula (n = 1 patient:2.8 %) −Graft rejection (n = 2 eyes:5.2 %) −Conjunctival prolapse (n = 1 eye:2.6 %) −Infectious complication (n = 0:0%)	The two patients presented with acute corneal graft rejection started again to use the SCLs after excessive topical steroid treatment.
Zhang et al [34]	0.80 ± 0.21 LogMAR	0.39 ± 0.13 LogMAR	0.25 ± 0.13 LogMAR	_	_	_	_	_

UCVA: uncorrected visual acuity, BCVA: best-corrected visual acuity, CLCVA: contact lens-corrected visual acuity, OSDI: Ocular Surface Disease Index.
* The information belonged to mix population group, with no separate report on post keratoplasty patients.

was achieved in 92 % [20,25] and 94.7 % [33] of post-keratoplasty eyes after fitting scleral CLs.

Similarly, corneoscleral CLs resulted in a significantly better visual acuity (0.17 ± 0.19 logMAR) compared to UCVA (1.05 ± 0.54 logMAR) and spectacle-corrected visual acuity (0.76 ± 0.50 logMAR) ($P < 0.001$) [24]. No significant difference was observed between PK and DALK in terms of visual acuity improvement after corneoscleral CL fitting [24]. Another study also showed a significantly better BCVA with corneoscleral CLs compared to spectacles (0.09 ± 0.12 versus 0.39 ± 0.34 logMAR, respectively, $P = 0.00002$), with a gain of ≥ 2 decimal acuity lines observed in 77 % of eyes after CL fitting [26]. A CLCVA of 20/20 and ≥ 20/30 was achieved in 51.8 % and 96.3 % of eyes, respectively [26]. Kumar et al. [29] described the outcomes of corneoscleral CL fitting in 16 post-PK eyes and noted an improvement in visual acuity from 0.63 ± 0.37 logMAR (with spectacle or soft CLs) to 0.07 ± 0.10 logMAR. Montalt et al. [31] observed that visual acuity significantly improved with corneoscleral CLs (0.02 ± 0.06 logMAR) compared to best spectacle-corrected visual acuity (0.22 ± 0.15 logMAR, $P = 0.007$). All eyes improved ≥ 2 lines of decimal visual acuity, with 33.3 % of cases achieving ≥ 5 decimal lines [31]. Furthermore, 7 of 9 cases reported a significant improvement in subjective quality of vision [31].

Wearing corneal rigid CLs also resulted in significantly better visual acuity (0.26 ± 0.13 logMAR) compared to UCVA (0.80 ± 0.22 logMAR) and spectacle-corrected visual acuity (0.39 ± 0.14 logMAR) ($P < 0.001$), with CLCVA > 20/40 in 63 % of eyes [34]. Bitoric and spherical corneal rigid CLs provided comparable visual acuity (0.10 ± 0.11 vs. 0.08 ± 0.12 logMAR, respectively, $P = 0.50$). Both lenses demonstrated improvement of visual acuity with CLs compared to spectacles ($P <$

0.05) [22]. Regarding hybrid CLs, CLCVA was also significantly better (0.05 logMAR) than UCVA (1.00 logMAR) and spectacle-corrected visual acuity (0.40 logMAR, P = 0.0001 for both comparisons) [28].

3.4.2. Daily wearing duration

Seven studies reported the mean comfortable daily wearing duration of CL ranging from 8 to 12.2 h/day [20,21,23,24,28,31,32]. Two studies reported the median comfortable daily wearing duration of 6 h/day for scleral CLs [30] and 15 h/day for different types of CLs [27]. Lee et al. [21] reported that 82 % of patients wore their scleral CLs for most or all waking hours. The daily scleral CL wear time was > 10 h/day in 56 % [25] and 75 % [23] of patients, between 6 and 10 h/day in 18 % [23] and 19 % [25], and < 6 h in 25 % [25]. Regarding corneoscleral CLs, the wearing time was ≥ 8 h/day in all eyes [31]. Three studies reported patients with limited CL wear. One patient complained of CL intolerance in both eyes after 3 h of corneoscleral CL wear [24]. Another patient with graft endothelial cell density < 700 cells/mm^2 could only tolerate corneoscleral CL for 4 to 6 h/day [26]. In another study, 2 of 20 patients (10 %) wearing hybrid CLs developed conjunctival hyperemia and intolerance after 4 and 5 h [28].

3.4.3. Subjective comfort

Seven studies reported subjective comfort, with most patients achieving comfortable CL fitting [21,24–27,31,32]. Subjective complaints associated with scleral CLs included difficulty with lens handling (29 %), haloes, blurriness, or haze (23 %), excessive fluid reservoir debris (23 %), and discomfort (6 %) [25]. A recent study evaluating post-keratoplasty patients fitted with scleral CLs reported a median comfort Visual Analogue Scale score of 84 for both subjective comfort and visual quality, and 85 for lens handling [27]. Navel et al. [32] reported median scores of 82.3 for “comfort” and 81 for “overall satisfaction” in 45 patients fitted with scleral CLs, of which 32 eyes had a history of keratoplasty. In another study, the majority of patients were comfortable (73 %) and achieved good-quality vision (71 %) while wearing scleral lenses [25]. Lee et al. [21] used the Ocular Surface Disease Index (OSDI) to evaluate the severity of ocular discomfort and vision-related function after fitting scleral CLs. They reported a 79 % improvement in the OSDI score in post-keratoplasty patients, from 77 ± 72.91 to 16 ± 9 (P = 0.017) [21]. Alipour et al. [24] reported ideal (71 %) or acceptable (29 %) subjective comfort in the majority of corneoscleral CL users. In another study, among the 9 eyes fitted with corneoscleral CLs, five patients (56 %) reported comfort, three (33 %) felt neither comfort nor discomfort, and one (11 %) reported discomfort [31].

3.4.4. CL discontinuation

A total of 7 studies reported CL dropouts after different periods of successful wear [23–26,28,32,33]. The rates of scleral CL discontinuation were 8 % [33], 12 % [23], 16 % [32], and 35 % [25]. Corneoscleral CL discontinuation was reported in 15 % and 39 % of eyes in two studies [24,26]. The dropout rate for hybrid CLs was 10 % [28]. Additionally, two studies reported no cases of CL discontinuation after 4 months of corneal rigid CL wear [22] and one year of corneoscleral CL wear [31].

The reasons for CL discontinuation varied among the studies. Difficulty with lens insertion/removal accounted for 2 % [24] and 17 % [25] of corneoscleral and scleral CL discontinuations, respectively. The rate of CL discontinuation related to intolerance and discomfort was 4 % for scleral CLs [25], 4 % [24] and 7 % [26] for corneoscleral CLs, and 10 % for hybrid CLs [28]. In three studies, corneal graft rejection was identified as the reason for scleral CL discontinuation in 3 % [23], 6 % [25], and 5 % [33] of eyes. Two patients resumed scleral CL wear after treatment of graft rejection and modification of CL parameters [33]. Other reasons included excessive limbal hyperemia due to pinguecula in 3 % [33], end-stage glaucoma in 3 % [23], visual dissatisfaction in 8 % [25], corneal graft edema in 7 % [26], and graft decompensation in 6 % of eyes [23]. One study reported only the number of patients who discontinued CL wear, without providing specific reasons [32].

Two of 11 patients (18 %) experienced discomfort during the corneoscleral CL fitting process and decided to drop out of the study [31]. Among 56 eyes reported by Alipour et al. [24], corneoscleral CLs were ordered for only 23 eyes. The main obstacles for ordering CLs were difficulties in handling and economic concerns [24]. In another study, 3 of 36 patients (8 %) discontinued scleral CL wear within a few weeks of dispensing, because they were unable to follow the wearing schedule or increase wearing time [23].

3.4.5. Corneal endothelial cell density and central corneal thickness

Five studies reported corneal endothelial cell density and/or central corneal thickness after CL fitting [24,26,28,31,33]. In one study, scleral CL wear led to a non-significant reduction in the mean endothelial cell density from 2,343 cells/mm^2 to 2,072 cells/mm^2 after six months [33]. In terms of corneoscleral CL wear, none of the eyes had an endothelial cell density of < 1500 cells/mm^2 after an average period of 22 months of CL wear [24]. Additionally, Montalt et al. [31] reported no significant differences in endothelial cell density (1710 ± 928 vs. 1716 ± 927 cells/mm^2, P = 0.21) or central corneal thickness (515 ± 69 vs. 518 ± 70 μm, P = 0.33) between baseline and after 12 months of corneoscleral CL wear. In patients using hybrid CLs, no significant difference was observed in central corneal thickness before (544 μm) and after 3 months of CL wear (549 μm, P = 0.38) [28].

3.4.6. Complications

Seven studies reported complications related to CL fitting [22–26,28,33], while one study found no complications associated with lens use [31]. Moreover, seven studies did not investigate complications following CL wear [20,21,27,29,30,32,34]. Three studies reported conjunctival hyperemia with scleral CLs (1 of 35 eyes, 3 %) [33], corneoscleral CLs (2 of 56 eyes, 4 %) [24], and hybrid CLs (2 of 20 eyes, 10 %) [28]. Microbial keratitis occurred with scleral CLs in 2 of 33 eyes (6 %) [23] and with corneoscleral CLs in 1 of 27 eyes (4 %) [26]. Three studies reported graft rejection episodes in 10 of 33 eyes (30 %) [23], 6 of 48 eyes (13 %) [25], and 2 of 38 eyes (5 %) [33] after fitting scleral CLs. In contrast, no episodes of graft rejection were reported for corneoscleral CLs [24,26,31] or hybrid CLs [28]. Most cases of graft rejection were successfully treated with frequent application of topical corticosteroids, although rejection reactions led to corneal graft failure in a small number of cases (one [25] and two [23] eyes). CL-induced corneal graft edema, unrelated to graft rejection, was observed in 2 of 33 eyes (6 %) with scleral CLs [23] and 2 of 27 eyes (7 %) with corneoscleral CLs [26]. Corneal edema occurred in both eyes of one patient with a bilateral corneal endothelial cell density of < 1000 cells/mm^2 [26]. In terms of spherical corneal rigid CLs, 6 of 14 eyes (43 %) experienced complications within the first 4 months after fitting, including giant papillary conjunctivitis (3 eyes, 21 %), superficial punctate keratitis (2 eyes, 14 %), and corneal abrasion (1 eye, 7 %) [22]. However, no complications were observed with bitoric corneal rigid CLs over the same period [22]. Lastly, epithelial trauma led to hybrid CL dropout in 2 of 20 eyes (10 %) due to a reduction in vault [28].

4. Discussion

This systematic review summarized the available evidence on visual rehabilitation, compliance, and potential complications associated with CL use in post-keratoplasty patients. For many years, full-thickness corneal transplantation has been the technique of choice for treating various corneal disorders. However, with the introduction of lamellar corneal procedures, PK has been replaced with anterior and posterior lamellar keratoplasty. Visual and refractive outcomes following PK and DALK are comparable [35]. Therefore, the number of DALK patients requiring CLs for visual rehabilitation is expected to increase. In contrast, posterior lamellar keratoplasty techniques, including Descemet stripping endothelial keratoplasty and Descemet membrane endothelial

keratoplasty, typically do not induce significant postoperative astigmatism. This likely explains the lack of studies reporting on CL fitting after these types of corneal transplantation.

Scleral CLs were the most frequently fitted lenses after corneal transplantation. The complex shape of the post-keratoplasty cornea, typically characterized by central flattening and peripheral steepening, presents challenges in achieving a stable fit with smaller-diameter corneal rigid CLs. Scleral CLs are supported by the sclera and can therefore vault the cornea and circumvent the graft-host junction due to their larger diameter and greater sagittal depth. Therefore, they may provide a more physiologically acceptable fit and prevent mechanical contact on the graft [4,7,13]. In this review, corneoscleral CLs were the second most fitted lens type after keratoplasty. These lenses are smaller in diameter than scleral lenses, potentially making insertion and removal easier. They are also less costly compared to scleral CLs. All studies investigating the role of rigid CLs reported a significantly better CLCVA compared to UCVA and habitual BCVA. The most frequent cause of reduced spectacle-corrected visual acuity after keratoplasty is the irregularity of the anterior corneal surface, which is often associated with increased higher-order aberrations [29]. Due to their rigidity, the tear layer formed behind a rigid CL masks most anterior corneal irregularities, thereby improving visual acuity in post-keratoplasty eyes [29].

The daily continuous wearing time is a crucial parameter for assessing the success of CLs, with a duration of 8 to 10 h/day often considered acceptable. This review indicates that patients could wear scleral CLs for longer periods compared to other types of CLs. In addition, high patient satisfaction has been reported with scleral CLs in terms of comfort, quality of vision, and lens handling [25,32]. The high comfort levels associated with scleral CL designs could be attributed to their bearing on the sclera, which minimizes contact with the cornea and the graft-host junction. Several factors affect the duration of comfortable scleral CL wear. Tear exchange beneath the lens edge, assessed by fluorescein dye penetration under the lens haptic, may enhance oxygen delivery to the graft and is associated with successful scleral CL wear for more than 10 h/day [20]. Additionally, scleral CL design is an influential factor. Since the asymmetry of the scleral surface increases with radial distance from the corneal apex, Kumar et al. [30] suggested that scleral CLs with a diameter greater than 15 mm may benefit from toricity within the landing zone. This design allows a more precise alignment of CL with the underlying sclera to potentially prolong comfortable lens wear.

The highest rate of CL discontinuation was observed in patients fitted with corneoscleral CLs [24] and scleral CLs [25], probably due to the fact that these types of CLs were most frequently used after keratoplasty. Difficulty with lens handling was the most frequent reason for discontinuing scleral CL wear [25]. On average, participants who abandoned scleral CL wear were older than those who continued using them, suggesting that reduced manual dexterity in older individuals makes handling scleral CL more difficult [25]. Additionally, patients' visual satisfaction may influence the decision to continue scleral lens wear. ‹ This study demonstrated that subjects who continued wearing scleral CLs were significantly more likely to be satisfied with their CLCVA compared to those who discontinued CL use [25]. Phan et al. [22] reported no discontinuation of rigid corneal CLs; however, the follow-up duration was limited to 4 months, which is shorter than the follow-up periods of other studies investigating CL discontinuation [22].

The most common complication was graft rejection, occurring in 5 % to 30 % of patients wearing scleral CLs [23,25,33]. This complication resulted in CL dropout in 6 eyes and graft failure in 3 eyes. However, it is not clear if CL wear was directly associated with graft failure. The toxic effects of preservatives, corneal hypoxia, and epithelial erosions caused by micro-trauma can lead to chronic ocular surface inflammation, which may trigger graft rejection. However, a similar incidence of graft rejection episodes (13 %–35 %) has been reported in post-keratoplasty patients who did not wear CLs [35]. Therefore, it can be concluded that the use of scleral CLs does not substantially increase the rate of corneal graft rejection.

Damage to the corneal epithelium has been reported with corneoscleral and hybrid CLs [22,28]. Ill-fitting corneal rigid CLs can lead to corneal micro-trauma and epithelial defects at the contact points between the CL and the corneal graft [22]. Similarly, hybrid CLs can cause corneal epithelial damage due to a loss of vault over time, leading to trauma at the location of the transition zone between the soft and rigid materials [28]. Epithelial defects increase the risk of developing corneal infection. Microbial keratitis was reported in patients using scleral and corneoscleral CLs [23,26]. Other risk factors for microbial keratitis associated with CLs include lens overwear and non-compliance with daily cleaning. These factors can lead to bacterial adhesion to CL surfaces [23].

Another concern regarding the use of scleral CLs in post-keratoplasty eyes is their potential impact on the graft endothelium. In this review, The incidence of CL-induced corneal graft edema was 6 % for scleral CLs [23] and 7 % for corneoscleral CLs [26]. Some studies may not have reported subclinical corneal edema, which could potentially lead to an underestimation of the incidence of CL-induced edema following keratoplasty. Penbe et al. [33] reported no statistically significant changes in corneal endothelial cell density six months after scleral CL wear. However, the baseline endothelial cell density in their study was high (2,343 cells/mm^2). A low endothelial cell count is frequently observed after PK due to surgical trauma, endothelial cell distribution change, or immunologic reactions [36]. Scleral CLs may not be the best choice for corneal grafts with low endothelial cell counts or pre-existing edema, as they may increase endothelial cell loss. Transient epithelial macrocysts have been observed at the periphery of corneal grafts in association with scleral CL wear, which typically resolve within 10 to 15 min after lens removal, with no long-term adverse effects on vision or comfort [37]. Schear et al. [38] reported that 4 of 26 PK eyes discontinued scleral CLs wear due to worsening corneal edema, which led to blurred vision within 1 to 2 h of lens wear. Kumar et al. [39] quantified the amount of scleral CL-induced corneal edema in PK eyes and reported 3 % corneal swelling across the central 6 mm after 6 h of CL wear, with greater swelling toward the graft-host junction inferiorly. It can be hypothesized that a reduced endothelial cell count, accumulation of waste products due to corneal hypoxia, structural changes in the graft, and the negative pressure underneath the scleral CL may contribute to graft edema. Additionally, one study reported the occurrence of hydrops following scleral contact lens wear [40]. In eyes with recurrent progressive ectasia, patients should be warned about the risk of hydrops, even in the absence of contact lens use [40].

This review has a number of limitations. First, most of the included studies are case series, as no clinical trials were identified. Second, some studies reported outcomes of CL fittings in mixed groups with different corneal conditions, constraining the availability of information specific to post-keratoplasty eyes. Third, the heterogeneity in eligibility criteria, follow-up duration, and types of corrective lenses used for habitual BCVA may affect the overall evaluation of CL-related visual rehabilitation outcomes.

5. Conclusion

CLs are safe and effective for visual rehabilitation in post-keratoplasty patients. However, despite the improved visual outcomes associated with CL use, patient compliance and the risk of complications remain significant challenges.

Funding.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence

the work reported in this paper.

Acknowledgements

None

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.clae.2025.102374.

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