COVID-19 and eye care

Scientific brief
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World Health Organization

Background

Coronavirus disease (COVID-19) has spread dramatically over the entire globe affecting all healthcare systems, since it was first identified in Wuhan, China in December 2019. The health implications have been of unprecedented magnitude, with the virus causing severe acute respiratory syndrome and the potential to affect almost every organ in the body. Significant progress has been made in understanding the disease, with reported cases of ocular involvement. It is beneficial to also examine the impact on eye care services to better understand the short to long-term impacts for persons needing to access eye care services.

A rapid systematic review was undertaken to inform this scientific brief. The review set out to assess the available peer-reviewed literature to analyze evidence on the following questions.

- What are the ocular manifestations associated with COVID-19 infection and the environmental restrictions placed?
- How has COVID-19 impacted eye care service delivery and education?
- What have been some alternative models of eye care service delivery that have been used during the COVID-19 pandemic?

Methods

An extensive literature review was performed on MEDLINE (via PubMed), EMBASE (via Elsevier), Cochrane Library (via Wiley), CINAHL (Cumulative Index to Nursing and Allied Health Literature), ARVO and AAO annual meeting Open Grey database, and medRxiv and bioXiv preprint platform during January 2021 – March 2023. 223 studies were screened, of which 103 were deemed relevant to the research questions listed in the introduction. Three reviewers screened titles and abstracts, and full texts of selected references. Data management included the removal of duplicates, the development of a database inclusion and exclusion criteria, and data for final inclusion in the study. No conflicts of interest were identified with the reviewers.

Review of the evidence

Ocular manifestations associated with COVID-19 infection

There are several ocular manifestations reported from people being infected with SARS-CoV-2 virus (COVID-19) infection, which include certain ocular diseases and refractive error. Ocular manifestations may be a presenting feature of COVID-19 or they may develop and persist several weeks after recovery *(1,2*).

Conjunctivitis has been widely reported across the world, in both children and adults, and was found to develop at any stage of the COVID-19 infection *(3-9)*. The incidence of conjunctivitis varied between studies, some reporting about 15% in a sample of children with a mean age of seven years infected with COVID-19 in Rome, Italy *(10)*, and as high as 31.6% in a sample of adults with a mean age of 66 years infected with COVID-19 in Hubei province, China *(11)*. In selected cases, this led to keratitis *(12)*. Three common ocular symptoms experienced were photophobia, sore eyes and itchy eyes *(13)*. Posterior eye manifestations were detected in some instances, including retinal haemorrhages, cotton wool spots, changes in retinal microvasculature and nerve fibre layer, and changes in choroidal vessels and thickness *(14-18)*, while vision-threatening manifestations included endogenous endophthalmitis, candida retinitis and tubercular choroidal abscess *(19)*. In persons with severe COVID-19, a significant incidence of rhino-orbital-cerebral mucormycosis was identified, requiring a multidisciplinary and resource-intensive approach due to its high mortality nature *(20,21).*

Eye care practitioners should be aware of the possible associations of ocular diseases with COVID-19, so that they ask relevant history, look for specific signs, advise appropriate tests and thereby mitigate the

spread of infection as well as diagnose and initiate early treatment for life and vision-threatening complications *(1)*.

Ocular manifestations associated with environmental restrictions placed during the COVID-19 pandemic

In response to the COVID-19 pandemic, governments around the world introduced travel restrictions, lockdowns, quarantine and stay-at-home orders in an attempt to minimize the spread of the virus. Ocular trauma occurring at home saw an increase during this period, with a study from Wenzhou City, China showing a significant rise in injuries from home improvement projects during the stay-at-home order *(22)*.

In the peak months of the pandemic, where there were heightened infection rates, 192 countries/territories elected to close schools, affecting nearly 1.5 billion children and young people *(23)*. Many schools enforced remote learning and children received their education virtually through digital devices.

During this period, studies showed an increase in myopia and myopia progression of school-age children *(24)*, particularly for younger school-age children *(25-28)*, although the rate was significantly reduced for children who participated in open-air activities for at least two hours per day and those who lived in detached houses *(29-31)*. Moreover, there were indications of potential myopia progression in children already receiving 0.01% atropine for myopia control *(32)*, while a slower progression was observed with children who were corrected with specialized lenses *(33).* Given the various factors at play, eye care personnel are strongly encouraged to consider multiple aspects in the management of myopia.

It is well documented that environmental factors, such as time spent outdoors and doing near work that includes screen-viewing activities, influence the development of myopia in children *(34)*. While digital device usage and staying indoors may not be the exclusive reasons for myopia progression, there is evidence supporting the importance of increased outdoor time and regulating children's exposure to digital screens *(35-37).*

Increased screen time during the period of COVID-19 restrictions, were also associated with an increase in dry eye symptoms *(38-40)* and digital eye strain *(41-44),* particularly for remote e-learners *(45)*.

Another restriction placed by governments was the wearing of face masks to minimize spread of COVID-19. Ocular discomfort often associated with dry eye disease was experienced by wearers of face masks (*46-48)*.

A positive outcome observed in Republic of Korea with the social distancing restrictions placed, was the significant reduction of infectious eye disease in all ages group, which saw an increase again once the social distancing restrictions were relaxed *(49).*

Impact of COVID-19 on eye care service delivery

The pandemic has a made a significant disruption to the delivery of eye care services. Although the health industry was deemed to be essential to continue operating, health resources were re-directed towards dealing with people with COVID-19 infections. Medical professions that weren't directly dealing with COVID-19 infections commonly saw drastic modifications to the nature of their work, particularly during the early stages of the pandemic. In some instances, eye care practitioners were deployed to provide care for COVID-19 patients *(50)*.

The number of patient visits and eye care treatments decreased considerably, and eye care services were de-prioritised in many instances. The severity of COVID-19 infection rates had a direct impact on the patient volume in many countries. In ophthalmology, visits were largely limited to urgent and emergent patients, with most routine check-ups and elective procedures being postponed *(51-55).* Cataract surgery volumes dropped significantly during certain periods of the pandemic with countries such as Australia, and India, reporting a 60-70% reduction compared to pre-pandemic level *(56,57)*. This had an economic impact on service providers, affecting the financial sustainability of services *(58).* The limitations on patients accessing services also affected vulnerable populations such as children, as the number of paediatric cases seen were significantly reduced during the peaks of the pandemic *(59,60)*. People who were not regarded to require immediate treatment, such as those with keratoconus, commonly had their condition worsen because of the delay in treatment *(61)*. Moreover, even when a person's condition rendered them eligible for care or if services remained open, people were hesitant to seek it *(62)*, often resulting in worsening of vision *(63)*.

Supply of medications and other critical services, such as corneal donation saw a decrease in some countries *(64)*.

Patient volumes of eye care services did increase following the lockdown periods *(65)*, however it has taken time to reach a complete recovery to pre-pandemic numbers in some places *(66)*. Access to eye care services has been hampered by staffing shortages at health care facilities caused by workers being exposed to and infected with COVID-19 *(67)*.

Depending on resources available, safety and hygiene protocols of eye care services were enhanced to minimize risk of exposure of COVID-19 to other patients and healthcare staff *(68-70)*, such as promoting physical distancing within the facility, installing protective barriers, and allowing for additional time for staff to clean surfaces. Clinical protocols were streamlined and alternative modes of service delivery such as telehealth were introduced to reduced number of patients at the facility at a given time *(71,72)*. Innovative methods were used to manage patient flow such as the use of text messages *(73)*.

Impact of COVID-19 on eye care education

With the suspension of face-to-face learning for training institutions particularly during the peaks of the pandemic, eye care education was still able to be maintained through remote learning as the mode of delivery *(74,75)*. Certain practical training and group study were rendered through video conferencing, and learners were able to see patients through telehealth platforms *(76)*. However, aspects of surgical training were delayed during the suspension periods *(77)*, leading to extensions of some training programs *(78)*. Continuing medical education also progressed through the lockdown periods, with a surge in online webinars *(79)*. Conferences and meetings (both scientific and clinical) were cancelled during the early peaks of the pandemic and returned to a hybrid mode allowing attendants to participate face-to-face or virtually. Tele-education which has emerged through the pandemic, has provided a unique opportunity and an overall positive impact on eye care education *(80)*.

Going forward, e-learning has enormous potential to supplement traditional education, with a significant number of virtual courses available to anyone with an internet connection and a willingness to learn wherever on the globe, with some limitations. The pandemic brought about new ways of learning through virtual simulators and tele-mentoring *(81)*. By embracing these changes, training programmes have been able to meet the difficulties of the pandemic and can continue to provide high-quality education in the future *(80-83)*. Many of these innovations will continue to be used long after the pandemic is over because they have shown that not all parts of the programme require face-to-face learning *(84)*.

Impact of COVID-19 on eye care research and existing gender inequities

The COVID-19 pandemic has had a profound impact on eye care research, and amplified the gender gaps that existed pre-pandemic. Research indicates that women were disproportionately burdened by the societal changes brought on by the pandemic, leading to a greater decline in women's productivity in research literature compared to men. For instance, the proportion of women first and corresponding authors in ophthalmology journals decreased from pre-pandemic levels of 31.1% and 24.6% to 27.4% and 20.4%, respectively, during the first 9 months of 2020 *(85)*. It is essential to closely monitor and address these gender gaps to ensure that women's contributions to eye care research are not undervalued or overlooked.

Eye care service delivery through telehealth during the COVID-19 pandemic

The pandemic led eye care services to drastically restrict patient volumes. Where resources were available, telehealth or video consultations were quickly deployed across routine and emergency eye care services to promote continuity of care and to assist patients who were reluctant or unable to leave their homes *(86)*.

Video consultations proved to be more useful than predicted in the remote management of eye conditions, resulting in a significant decrease in the number of patients attending the hospital and potentially reducing the risk of infection *(86-88).* Patients with ocular surface conditions, oculoplastic conditions and those who needed follow-up management benefited from the telehealth consultations *(89-91)*. Studies showed there was modest correlation between the virtual systems measuring visual acuity compared to in-clinic measurements *(92,93)*.

Based on finding from several studies, eye care practitioners and patients, were both satisfied with the service delivered through telehealth, and would consider it for future consultations *(94-96)*. Combining telehealth with other technical devices to support patient management and patient education, may improve overall patient outcomes *(97,98).* Adequate practitioner training and support will also determine the successful application of telehealth for eye care service delivery *(99)*.

Prior to the pandemic, existing telehealth and other virtual systems commonly had a low uptake. The pandemic has propelled the use and uptake of telehealth and other virtual systems to address the demands and have been further developed to grow into long-term solutions as countries and systems adjust to the new normal. The added benefits of telehealth should be considered when evaluating its role in eye care service delivery. Telehealth can make services more streamlined by triaging patients prior to arrival into the service to avoid unnecessary visits and exposure risks. It also reduces travel and its associated carbon footprints. Telehealth has the potential to make the distribution of scarce healthcare resources more efficient and equitable, increasing access for patients in remote areas where there is a shortage of eye care practitioners *(100)*.

Persistent disparities in accessing telehealth services among ethnic/racial minorities, older patients, and non-English-speaking individuals highlight the need for addressing these issues as telehealth continues expands in the future *(101,102)*. Investment into telehealth systems and infrastructure need to be made across different settings, including those with limited resources for services to be equitable and accessible. This investment will also build the resilience of our health systems to face future challenges and disruptions.

Limitations

Many of the studies were focused on tertiary eye care services of ophthalmology, limiting the knowledge on the impact of COVID-19 on primary and secondary eye care services. Many of the studies also had a small sample size; were cross-sectional or retrospective in nature; and selection of study participants were preferential on the basis of the exposure to COVID-19 in some cases *(103)*.

Conclusions

The COVID-19 pandemic has impacted eye care in several ways including ocular manifestations associated with SARS-CoV-2 virus itself, and ocular manifestations associated with environmental restrictions placed during the pandemic, leading to a worsening of certain conditions such as conjunctivitis and myopia. Eye care services mostly showed a reduction in patient volume as resources were re-directed to accommodate patients with COVID-19 infections. Eye care education was largely unaffected as courses and seminars continued through remote learning. A promising outcome from the pandemic is the emergence of telehealth, which shows potential to positively disrupt and build resilience in the delivery of eye care services going into the future.

Plans for updating

WHO continues to monitor the situation closely for any changes that may affect the information in this Scientific brief. Should any factors change, WHO will issue a further update. Otherwise, the expected validity of this brief will be reviewed 1 year after the date of publication.

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References

1. Sen M, Honavar SG, Sharma N, Sachdev MS. COVID-19 and Eye: A Review of Ophthalmic Manifestations of COVID-19. Indian journal of ophthalmology, 2021; 69(3), 488–509. https://doi.org/10.4103/ijo.IJO_297_21
2. Wan KH, Lui GCY, Poon KCF, Ng SSS, Young AL, Hui DSC, Tham CCY, Chan PKS, Pang CP, Chong K KL. Ocular surface disturbance in patients after acute COVID-19. Clinical and Experimental Ophthalmology, 2021; 50(4), 398-406. https://doi.org/10.1111/ceo.14066
3. Bostanci Ceran B, Ozates S. Ocular manifestations of coronavirus disease 2019. Graefe's Archive for Clinical and Experimental Ophthalmology, 2020; 258(9), 1959-1963.
4. Boz AAE, Atum M, Çakır B, Karabay O, Çelik E, Alagöz G. Outcomes of the ophthalmic examinations in patients infected by SARS-CoV-2. Ocular Immunology and Inflammation, 2021; 29:4, 638-641. doi: 10.1080/09273948.2020.1844904
5. D'Amico Ricci G, Del Turco C, Belcastro E, Palisi M, Romano MR, Pinna A.,et al.. COVID-19 and acute conjunctivitis: Controversial data from a tertiary referral Italian center. European Journal of Ophthalmology, 2021; 31(6), 2910-2913. doi: 10.1177/1120672121991049
6. Danesh-Meyer HV, McGhee CNJ. Implications of COVID-19 for Ophthalmologists. American Journal of Ophthalmology, 2021; 223, 108-118. https://doi.org/10.1016/j.ajo.2020.09.027
7. Güemes-Villahoz N, Burgos-Blasco B, García-Feijoó J, Sáenz-Francés F, Arriola-Villalobos P, Martinez-de-la-Casa J, et al. Conjunctivitis in COVID-19 patients: Frequency and clinical presentation. Graefe's Archive for Clinical and Experimental Ophthalmology, 2020; 258(11), 2501–2507. https://doi.org/10.1007/s00417-020-04916-0
8. Chen L, Deng C, Chen X, Zhang X, Chen B, Yu H, et al. Ocular manifestations and clinical characteristics of 535 cases of COVID-19 in Wuhan, China: A cross-sectional study. Acta Ophthalmologica, 2020; 98(8), e951–e959. https://doi.org/10.1111/aos.14472
9. Mocanu V, Bhagwani D, Sharma A, Borza C, Rosca CI, Stelian M,,et al. COVID-19 and the Human Eye: Conjunctivitis, a Lone COVID-19 Finding - A Case-Control Study. Medical Principles and Practice, 2022; 31(1), 66-73. doi: 10.1159/000521808
10. Valente, P., Iarossi, G., Federici, M., Petroni, S., Palma, P., Cotugno, N., et al. Ocular manifestations and viral shedding in tears of pediatric patients with coronavirus disease 2019: A preliminary report. Journal of AAPOS: The Official Publication of the American Association for Pediatric Ophthalmology and Strabismus, 2020; 24(4), 212–215. https://doi.org/10.1016/j.jaapos.2020.05.002
11. Wu P, Duan F, Luo C, Liu Q, Qu X, Liang L, et al. Characteristics of Ocular Findings of Patients With Coronavirus Disease 2019 (COVID-19) in Hubei Province, China. JAMA Ophthalmology, 2020; 138(5), 575–578. doi:10.1001/jamaophthalmol.2020.1291
12. Lima LCF, Moraes Junior HV, Moraes HMV. COVID-19 Ocular Manifestations in the Early Phase of Disease. Ocul Immunol Inflamm. 2021; May 19;29(4):666-668. doi: 10.1080/09273948.2021.1887278
13. Pardhan S, Vaughan M, Zhang J, Smith, Havovi C. Sore eyes as the most significant ocular symptom experienced by people with COVID-19: A comparison between pre-COVID-19 and during COVID-19 states. BMJ Open Ophthalmology, 2020; 5(1), e000632
14. Invernizzi A, Torre A, Parrulli S, Zicarelli F, Schiuma M, Colombo V, et al. Retinal findings in patients with COVID-19: Results from the SERPICO-19 study. EClinicalMedicine, 2020; 27, 100550. https://doi.org/10.1016/j.eclinm.2020.100550
15. Shantha JG, Fashina T, Stittleburg V, Randleman C, Ward L, Regueiro M, et al. COVID-19 and the eye: Systemic and laboratory risk factors for retinopathy and detection of tear film SARS-CoV-2 RNA with a triplex RT-PCR assay. PloS one, 2022; 17(11), e0277301. https://doi.org/10.1371/journal.pone.0277301
16. Wang S, Wang J, Hu J, Wang N. Retinal microvascular impairment in COVID-19 patients: A meta-analysis. Immun Inflamm Dis, 2022 Jun;10(6):e619. doi: 10.1002/iid3.619

17. Erdem S, Karahan M, Ava S, Dursun ME, Dursun B, Hazar L, et al. Evaluation of choroidal thickness in patients who have recovered from COVID-19. Int Ophthalmol. 2022 Mar;42(3):841-846. doi: 10.1007/s10792-021-02049-9.

18. Burgos-Blasco B, Güemes-Villahoz N, Vidal-Villegas B, Martinez-de-la-Casa JM, Garcia-Feijoo J, Donate-Lopez J, et al. One-Year Changes in Optic Nerve Head Parameters in Recovered COVID-19 Patients. J Neuroophthalmol. 2022 Dec 1;42(4):476-482. doi: 10.1097/WNO.0000000000001626..

19. Goyal M, Murthy SI, Annum S. Retinal manifestations in patients following COVID-19 infection: A consecutive case series. Indian journal of ophthalmology, 2021; 69(5), 1275–1282. https://doi.org/10.4103/ijo.IJO_403_21

20. Bayram N, Ozsaygılı C, Sav H, Tekin Y, Gundogan M, Pangal E, et al. Susceptibility of severe COVID-19 patients to rhino-orbital mucormycosis fungal infection in different clinical manifestations. Japanese journal of ophthalmology, 2021; 65(4), 515–525. https://doi.org/10.1007/s10384-021-00845-5

21. Al-Ani RM, Al Tameemi KM. COVID-19-related Rhino-orbital-cerebral Mucormycosis. Qatar Med J. 2022 Oct 6;2022(4):47. doi: 10.5339/qmj.2022.47. PMID: 36258686; PMCID: PMC9574569.

22. Wu C, Patel SN, Jenkins TL, Obeid A, Ho AC, Yonekawa Y. Ocular trauma during COVID-19 stay-at-home orders: a comparative cohort study. Current opinion in ophthalmology, 2020; 31(5), 423–426. https://doi.org/10.1097/ICU.0000000000000687

23. UNESCO. How Many Students Are at Risk of Not Returning to School? Paris: UNESCO; 2020. (https://unesdoc.unesco.org/ark:/48223/pf0000373992, accessed 20 February 2023)

24. Mohan A, Sen P, Peeush P, Shah C, Jain E. Impact of online classes and home confinement on myopia progression in children during COVID-19 pandemic: Digital eye strain among kids (DESK) study 4. Indian journal of ophthalmology, 2022; 70(1), 241–245. https://doi.org/10.4103/ijo.IJO_1721_21

25. Chang P, Zhang B, Lin L, Chen R, Chen S, Zhao Y, Qu J. Comparison of Myopic Progression before, during, and after COVID-19 Lockdown. Ophthalmology, 2021; 128(11), 1655–1657. https://doi.org/10.1016/j.ophtha.2021.03.029

26. Wang J, Li Y, Musch DC, Wei N, Qi X, Ding G, et al. Progression of Myopia in School-Aged Children After COVID-19 Home Confinement. JAMA ophthalmology, 2021; 139(3), 293–300. https://doi.org/10.1001/jamaophthalmol.2020.6239

27. Wang W, Zhu L, Zheng S, Ji Y, Xiang Y, Lv B, et al. Survey on the Progression of Myopia in Children and Adolescents in Chongqing During COVID-19 Pandemic. Frontiers in public health, 2021; 9, 646770. https://doi.org/10.3389/fpubh.2021.646770

28. Ma D, Wei S, Li SM, Yang X, Cao K, Hu J, et al. The Impact of Study-at-Home During the COVID-19 Pandemic on Myopia Progression in Chinese Children. Front Public Health. 2022; Jan 6;9:720514. doi: 10.3389/fpubh.2021.720514

29. Alvarez-Peregrina C, Martinez-Perez C, Villa-Collar C, Andreu-Vázquez C, Ruiz-Pomeda A, Sánchez-Tena M Á. Impact of COVID-19 Home Confinement in Children's Refractive Errors. International journal of environmental research and public health, 2021; 18(10), 5347. https://doi.org/10.3390/ijerph18105347

30. Aslan F, Sahinoglu-Keskek N. The effect of home education on myopia progression in children during the COVID-19 pandemic. Eye (London, England), 2021; 1–6. https://doi.org/10.1038/s41433-021-01655-2

31. Xu L, Ma Y, Yuan J, Zhang Y, Wang H, Zhang G, et al. Myopic Epidemiology and Intervention Study. COVID-19 Quarantine Reveals That Behavioral Changes Have an Effect on Myopia Progression. Ophthalmology, 2021; 128(11), 1652–1654. https://doi.org/10.1016/j.ophtha.2021.04.001

32. Erdinest N, London N, Levinger N, Lavy I, Pras E, Morad Y. Decreased effectiveness of 0.01% atropine treatment for myopia control during prolonged COVID-19 lockdowns. Contact lens & anterior eye: the journal of the British Contact Lens Association, 2021; 101475. https://doi.org/10.1016/j.clae.2021.101475

33. Choi KY, Chun RKM, Tang WC, To CH, Lam CS, Chan HH. Evaluation of an Optical Defocus Treatment for Myopia Progression Among Schoolchildren During the COVID-19 Pandemic. JAMA Netw Open. 2022; Jan 4;5(1):e2143781. doi: 10.1001/jamanetworkopen.2021.43781

34. Wolffsohn JS, Flitcroft DI, Gifford KL, Jong M, Jones L, Wildsoet CF, et al. IMI - Myopia Control Reports Overview and Introduction. Investigative ophthalmology & visual science, 2019; 60(3), M1–M19. https://doi.org/10.1167/iovs.18-25980

35. Wong CW, Tsai A, Jonas JB, Ohno-Matsui K, Chen J, Ang M, Ting D. Digital Screen Time During the COVID-19 Pandemic: Risk for a Further Myopia Boom?. American journal of ophthalmology, 2021;223, 333–337. https://doi.org/10.1016/j.ajo.2020.07.034

36. Liu J, Li B, Sun Y, Chen Q, Dang J. Adolescent Vision Health During the Outbreak of COVID-19: Association Between Digital Screen Use and Myopia Progression. Frontiers in pediatrics, 2021; 9, 662984. https://doi.org/10.3389/fped.2021.662984

37. Liu J, Li B, Chen Q, Dang J. Student Health Implications of School Closures during the COVID-19 Pandemic: New Evidence on the Association of e-Learning, Outdoor Exercise, and Myopia. Healthcare (Basel, Switzerland), 2021; 9(5), 500. https://doi.org/10.3390/healthcare9050500

38. Pavithra S, Sundar D. Assessment Of Dry Eye Symptoms And Quality Of Sleep In Engineering Students During The Covid-19 Pandemic. International Journal of Research in Pharmaceutical Sciences. 2020;1202-1207. 10.26452/ijrps.v11iSPL1.3593.

39. Saldanha IJ, Petris R, Makara M, Channa P, Akpek EK. Impact of the COVID-19 pandemic on eye strain and dry eye symptoms. The ocular surface, 2021; 22, 38–46. https://doi.org/10.1016/j.jtos.2021.06.004

40. Salinas-Toro D, Cartes C, Segovia C, Alonso MJ, Soberon B, Sepulveda M, et al. High frequency of digital eye strain and dry eye disease in teleworkers during the coronavirus disease (2019) pandemic. International journal of occupational safety and ergonomics: JOSE, 2021; 1–6 https://doi.org/10.1080/10803548.2021.1936912

41. Bahkir FA, Grandee SS. Impact of the COVID-19 lockdown on digital device-related ocular health. Indian journal of ophthalmology, 2020;68(11), 2378–2383. https://doi.org/10.4103/ijo.IJO_2306_20

42. Hundekari J, Sisodiya R, Kot L. Smartphone Vision Syndrome Associated with Prolonged Use of Digital Screen for Attending Online Classes during COVID-19 Pandemic among Medical Students: A Cross-sectional Study. Journal of clinical and diagnostic research, 2021; 15(1):NC01-NC05. https://doi.org/10.7860/JCDR/2021/46651.14399

43. Sundar D, Niveditha M. Digital Vision Syndrome (DVS) Among Medical Students During Covid-19 Pandemic Curfew. Int J Res Pharm Sci. 2020;1128-1133. doi:10.26452/ijrps.v11iSPL1.3557

44. Ganne P, Najeeb S, Chaitanya G, Sharma A, Krishnappa NC. Digital Eye Strain Epidemic amid COVID-19 Pandemic - A Cross-sectional Survey. Ophthalmic Epidemiol. 2021;28(4):285–292. https://doi.org/10.1080/09286586.2020.1862243

45. Mohan A, Sen P, Shah C, Jain E, Jain S. Prevalence and risk factor assessment of digital eye strain among children using online e-learning during the COVID-19 pandemic: Digital eye strain among kids (DESK study-1). Indian J Ophthalmol. 2021;69(1):140–144. https://doi.org/10.4103/ijo.IJO_2535_20

46. Boccardo L. Self-reported symptoms of mask-associated dry eye: A survey study of 3,605 people. Contact lens & anterior eye : the journal of the British Contact Lens Association, 2021; 101408. https://doi.org/10.1016/j.clae.2021.01.003

47. Mastropasqua L, Lanzini M, Brescia L, D'Aloisio R, Nubile M, Ciancaglini M, et al. Face Mask-Related Ocular Surface Modifications During COVID-19 Pandemic: A Clinical, In Vivo Confocal Microscopy, and Immune-Cytology Study. Translational Vision Science & Technology. 2021; 10(3):22. DOI: 10.1167/tvst.10.3.22.

48. Scalinci SZ, Pacella E, Battagliola ET. Prolonged face mask use might worsen dry eye symptoms. Indian Journal of Ophthalmology. 2021; 69(6):1508–1510. https://doi.org/10.4103/ijo.IJO_2641_20

49. Lee WR, Kim LH, Lee GM, Cheon J, Kwon YD, Noh JW, Yoo KB. Effect of COVID-19-Related Interventions on the Incidence of Infectious Eye Diseases: Analysis of Nationwide Infectious Disease Incidence Monitoring Data. Int J Public Health. 2022; Oct 20;67:1605211. doi: 10.3389/ijph.2022.1605211

50. Lim C, De Silva I, Moussa G, Islam T, Osman L, Malick H, et al. Redeployment of ophthalmologists in the United Kingdom during the Coronavirus Disease Pandemic. European Journal of Ophthalmology. 2021; 31(5):2268–2274. https://doi.org/10.1177/1120672120953339

51. El Hamichi S, Gold A, Heier J, Kiss S, Murray TG. Impact of the COVID-19 Pandemic on Essential Vitreoretinal Care with Three Epicenters in the United States. Clinical Ophthalmology. 2020; 14:2593–2598. https://doi.org/10.2147/OPTH.S267950

52. Yehezkeli V, Rotenstreich Y, Haim L, Sher I, Achiron A, Belkin A. Ophthalmic emergency-room visits during the Covid-19 pandemic - a comparative study. BMC Ophthalmology. 2021; 21(1):210. https://doi.org/10.1186/s12886-021-01976-6

53. Moon JY, Miller JB, Katz R, Ta T, Szypko C, Garg I, et al. The Impact of the COVID-19 Pandemic on Ophthalmic Care at an Eye-Specific Emergency Department in an Outbreak Hotspot. Clinical Ophthalmology. 2020; 14:4155–4163. https://doi.org/10.2147/OPTH.S285223

54. Vu AF, Kodati S, Lin P, Bodaghi B, Emami-Naeini P, & COVID-19 Practice Patterns Study Group. Impact of the COVID-19 pandemic on uveitis patient care. The British Journal of Ophthalmology. 2023;107:790-794. https://doi.org/10.1136/bjophthalmol-2021-320368

55. Sanjay S, Leo SW, Au Eong KG, Adriono GA, Fong KC, Anand K, Kadarisman RS, Granet DB, Mahendradas P, Shetty R, Souza SD, Iyer SP. Global Ophthalmology Practice Patterns during COVID-19 Pandemic and Lockdown. Ophthalmic Epidemiol. 2022 Jun;29(3):233-244. doi: 10.1080/09286586.2021.1934037

56. Phakey S, Hall AJ, Lim LL. Impact of COVID-19 on ophthalmic surgery in Australia. Investigative Ophthalmology & Visual Science. 2022;63(7):2155 – A0183

57. Gupta PC, Aggarwal S, Jain P, Jugran D, Sharma M, Pandav SS, Ram J. Impact of COVID-19 pandemic on cataract surgical volume: A North Indian experience. Indian J Ophthalmol. 2021; Dec;69(12):3648-3650. doi: 10.4103/ijo.IJO_1069_21

58. Agarwal D, Saxena R, Sinha R, Mishra D, Sachdev MS, Sharma N. All India Ophthalmological Society Financial Impact Survey on ophthalmology practice in India during COVID-19. Indian Journal of Ophthalmology. 2021; 69(8):2196–2201. https://doi.org/10.4103/ijo.IJO_1116_21

59. Wood M, Gray J, Raj A, Gonzalez-Martin J, Yeo D. The Impact of the First Peak of the COVID-19 Pandemic on a Paediatric Ophthalmology Service in the United Kingdom: Experience from Alder Hey Children's Hospital. The British and Irish Orthoptic Journal. 2021; 17(1):56–61. https://doi.org/10.22599/bioj.164

60. Franzolin E, Longo R, Gusson E, Ficial B, Marchini G. Pediatric eye emergency department activity during the first wave of Covid-19 pandemic. Italian Journal of Pediatrics. 2021; 47(1):217. https://doi.org/10.1186/s13052-021-01167-5

61. Shah H, Pagano L, Vakharia A, Coco G, Gadhvi KA, Kaye SB, et al. Impact of COVID-19 on keratoconus patients waiting for corneal cross linking. European Journal of Ophthalmology. 2021; 31(6):3490–3493. https://doi.org/10.1177/11206721211001315

62. Muralikrishnan J, Christy JS, Srinivasan K, Subburaman GB, Shukla AG, Venkatesh R, et al. Access to eye care during the COVID-19 pandemic, India. Bulletin of the World Health Organization. 2022; 100(2):135–143. https://doi.org/10.2471/BLT.21.286368

63. Patel LG, Peck T, Starr MR, Ammar MJ, Khan MA, Yonekawa Y, et al. Clinical Presentation of Rhegmatogenous Retinal Detachment during the COVID-19 Pandemic: A Historical Cohort Study. Ophthalmology. 2021; 128(5):686–692. https://doi.org/10.1016/j.ophtha.2020.10.009

64. Thuret G, Courrier E, Poinard S, Gain P, Baud'Huin M, Martinache I, et al. One threat, different answers: the impact of COVID-19 pandemic on cornea donation and donor selection across Europe. The British Journal of Ophthalmology. 2022; 106(3):312–318. https://doi.org/10.1136/bjophthalmol-2020-317938

65. Das AV, Chaurasia S, Vaddavalli PK, Garg P. Year one of COVID-19 pandemic in India: Effect of lockdown and unlock on trends in keratoplasty at a tertiary eye centre. Indian Journal of Ophthalmology. 2021; 69(12):3658–3662. https://doi.org/10.4103/ijo.IJO_1740_21

66. Das AV, Rao P, Shanbhag S, Singh S, Basu S. Waves of COVID-19 Pandemic: Effect on Ocular Surface Services at a Tertiary Eye Center in India. Cureus. 2021; 13(12):e20719. https://doi.org/10.7759/cureus.20719

67. Davila-Siliezar P, Wer A, Barnoya J. SARS-CoV-2 seroprevalence in healthcare workers in a high-volume ophthalmology centre in Guatemala. Annals of Medicine. 2021; 53(1):1956–1959. https://doi.org/10.1080/07853890.2021.1993325

68. Korobelnik JF, Loewenstein A, Eldem B, Joussen AM, Koh A, Lambrou GN, et al. Anti-VEGF intravitreal injections in the era of COVID-19: responding to different levels of epidemic pressure. Graefe's Archive for Clinical and Experimental Ophthalmology. 2021; 259(3):567–574. https://doi.org/10.1007/s00417-021-05097-0

69. Korobelnik JF, Loewenstein A, Eldem B, Joussen AM, Koh A, Lambrou GN, et al. 2020. Guidance for anti-VEGF intravitreal injections during the COVID-19 pandemic. Graefe's Archive for Clinical and Experimental Ophthalmology. 2020; 258(6):1149–1156. https://doi.org/10.1007/s00417-020-04703-x

70. Sadhu S, Agrawal R, Pyare R, Pavesio C, Zierhut M, Khatri A, et al. COVID-19: Limiting the Risks for Eye Care Professionals. Ocular Immunology and Inflammation. 2020; 28(5):714–720. https://doi.org/10.1080/09273948.2020.1755442

71. Sethi K, Levine ES, Roh S, Marx JL, Ramsey DJ. Modeling the impact of COVID-19 on Retina Clinic Performance. BMC Ophthalmology. 2021; 21(1):206. https://doi.org/10.1186/s12886-021-01955-x

72. Moss HE, Ko MW, Mackay DD, Chauhan D, Gutierrez KG, Villegas NC, et al. The Impact of COVID-19 on Neuro-Ophthalmology Office Visits and Adoption of Telemedicine Services. Journal of Neuro-Ophthalmology. 2021; 41(3):362–367. https://doi.org/10.1097/WNO.0000000000001356

73. Lai T, Lee M, Au A, Tang H, Tang E, Li K. The use of short message service (SMS) to reduce outpatient attendance in ophthalmic clinics during the coronavirus pandemic. International Ophthalmology. 2021; 41(2):613–620. https://doi.org/10.1007/s10792-020-01616-w

74. Brodin AC, Tamhankar MA, Whitehead G, MacKay D, Kim BJ, O'Brien JM. Approach of an Academic Ophthalmology Department to Recovery During the Coronavirus Pandemic. Clinical Ophthalmology. 2022; 16:695–704. https://doi.org/10.2147/OPTH.S342300

75. Sehgal S, Shinde L, Madheswaran G, Mukherjee P, Verkicharla P, Easwaran S, Bandamwar K. Impact of COVID-19 on Indian optometrists: A student, educator, and practitioner's perspective. Indian Journal of Ophthalmology. 2021; 69(4):958–963. https://doi.org/10.4103/ijo.IJO_3386_20

76. DeVaro SN, Uner OE, Khalifa YM, Graubart EB. Ophthalmology Education in COVID-19: A Remote Elective for Medical Students. Journal of Academic Ophthalmology. 2020; 12(2):e165–e170. https://doi.org/10.1055/s-0040-1716695

77. Alahmadi AS, Alhatlan HM, Bin Helayel H, Khandekar R, Al Habash A, Al-Shahwan S. Residents' Perceived Impact of COVID-19 on Saudi Ophthalmology Training Programs-A Survey. Clinical Ophthalmology. 2020; 14:3755–3761. https://doi.org/10.2147/OPTH.S283073

78. Silva N, Laiginhas R, Meireles A, Barbosa Breda J. Impact of the COVID-19 Pandemic on Ophthalmology Residency Training in Portugal. Acta Medica Portuguesa. 2020; 33(10):640–648. https://doi.org/10.20344/amp.14341

79. Rana R, Kumawat D, Sahay P, Gour N, Patel S, Samanta R, Singh A, Mittal S. Perception among ophthalmologists about webinars as a method of continued medical education during COVID-19

pandemic. Indian Journal of Ophthalmology. 2021; 69(4):951–957. https://doi.org/10.4103/ijo.IJO_3136_20

80. Chatziralli I, Ventura CV, Touhami S, Reynolds R, Nassisi M, Weinberg T, et al. Transforming ophthalmic education into virtual learning during COVID-19 pandemic: a global perspective. Eye (London, England). 2021; 35(5):1459–1466. https://doi.org/10.1038/s41433-020-1080-0

81. Ferrara M, Romano V, Steel DH, Gupta R, Iovino C, van Dijk E, OphthaTraining Group, Romano MR. Reshaping ophthalmology training after COVID-19 pandemic. Eye (London, England). 2020; 34(11):2089–2097. https://doi.org/10.1038/s41433-020-1061-3

82. Dasgupta S, Shakeel T, Gupta P, Kakkar A, Vats V, Jain M, et al. Impact of ophthalmic webinars on the resident's learning experience during COVID-19 pandemic: An insight into its present and future prospects. Indian Journal of Ophthalmology. 2021; 69(1):145–150. https://doi.org/10.4103/ijo.IJO_2279_20

83. Falfoul Y, Chebil A, Halouani S, Bouraoui R, Fekih O, El Matri L. E-learning for Ophthalmology Training Continuity During COVID-19 Pandemic: Satisfaction of residents of Hédi Raies Institut of Ophthalmology of Tunis. La Tunisie Medicale. 2021; 99(2):207–214.

84. Succar T, Beaver HA, Lee AG. Impact of COVID-19 pandemic on ophthalmology medical student teaching: educational innovations, challenges, and future directions. Survey of Ophthalmology. 2022; 67(1):217-225. https://doi.org/10.1016/j.survophthal.2021.03.011

85. Nguyen AX, Trinh XV, Kurian J, Wu AY. Impact of COVID-19 on longitudinal ophthalmology authorship gender trends. Graefe's Archive for Clinical and Experimental Ophthalmology. 2021; 259(3):733–744. https://doi.org/10.1007/s00417-021-05085-4

86. Kilduff CL, Thomas AA, Dugdill J, Casswell EJ, Dabrowski M, Lovegrove C, et al. Creating the Moorfields' virtual eye casualty: video consultations to provide emergency teleophthalmology care during and beyond the COVID-19 pandemic. BMJ Health & Care Informatics. 2020; 27(3):e100179. https://doi.org/10.1136/bmjhci-2020-100179

87. Arntz A, Khaliliyeh D, Cruzat A, Rao X, Rocha G, Grau A, Altschwager P, Azócar V. Open-care telemedicine in ophthalmology during the COVID-19 pandemic: a pilot study. Archivos de la Sociedad Espanola de Oftalmologia. 2020; 95(12):586–590. https://doi.org/10.1016/j.oftal.2020.09.005

88. Newman-Casey PA, De Lott L, Cho J, Ballouz D, Azzouz L, Saleh S, Woodward MA. Telehealth-based Eye Care During the COVID-19 Pandemic: Utilization, Safety, and the Patient Experience. American Journal of Ophthalmology. 2021; 230:234–242. https://doi.org/10.1016/j.ajo.2021.04.014

89. Wu X, Chen J, Yun D, Yuan M, Liu Z, Yan P, et al. Effectiveness of an Ophthalmic Hospital-Based Virtual Service during the COVID-19 Pandemic. Ophthalmology. 2021; 128(6):942–945. https://doi.org/10.1016/j.ophtha.2020.10.012

90. Jamison A, Diaper C, Drummond S, Tejwani D, Gregory ME, Cauchi P, Crofts K, Chadha V. Telemedicine in Oculoplastics: The Real-Life Application of Video Consultation Clinics. Ophthalmic Plastic and Reconstructive Surgery. 2021; 37(3S):S104–S108. https://doi.org/10.1097/IOP.0000000000001852

91. Assayag E, Tsessler M, Wasser LM, Drabkin E, Reich E, Weill Y, Zadok D, Nair AG, Andron A. Telemedicine comes of age during coronavirus disease 2019 (COVID-19): An international survey of oculoplastic surgeons. European Journal of Ophthalmology. 2021; 31(6):2881–2885. https://doi.org/10.1177/1120672120965471

92. Khurana RN, Hoang C, Khanani AM, Steklov N, Singerman LJ. A Smart Mobile Application to Monitor Visual Function in Diabetic Retinopathy and Age-Related Macular Degeneration: The CLEAR Study. American Journal of Ophthalmology. 2021; 227:222–230. https://doi.org/10.1016/j.ajo.2021.03.033

93. Silverstein E, Williams JS, Brown JR, Bylykbashi E, Stinnett SS. Teleophthalmology: Evaluation of Phone-based Visual Acuity in a Pediatric Population. American Journal of Ophthalmology. 2021; 221:199–206. https://doi.org/10.1016/j.ajo.2020.08.007

94. Staffieri SE, Mathew AA, Sheth SJ, Ruddle JB, Elder JE. Parent satisfaction and acceptability of telehealth consultations in pediatric ophthalmology: initial experience during the COVID-19 pandemic. Journal of AAPOS : the official publication of the American Association for Pediatric Ophthalmology and Strabismus. 2021; 25(2):104–107. https://doi.org/10.1016/j.jaapos.2020.12.003

95. Shahid SM, Anguita R, daCruz L. Telemedicine for postoperative consultations following vitrectomy for retinal detachment repair during the COVID-19 crisis: a patient satisfaction survey. Canadian Journal of Ophthalmology. Journal Canadien D'ophtalmologie. 2021; 56(2):e46–e48. https://doi.org/10.1016/j.jcjo.2020.11.011

96. Azarcon CP, Ranche F, Santiago DE. Tele-Ophthalmology Practices and Attitudes in the Philippines in Light of the COVID-19 Pandemic: A Survey. Clinical Ophthalmology. 2021; 15:1239–1247. https://doi.org/10.2147/OPTH.S291790

97. Ooms A, Shaikh I, Patel N, Kardashian-Sieger T, Srinivasan N, Zhou B, et al. Use of Telepresence Robots in Glaucoma Patient Education. Journal of Glaucoma. 2021; 30(3):e40–e46. https://doi.org/10.1097/IJG.0000000000001731

98. Chen H, Pan X, Yang J, Fan J, Qin M, Sun H, et al. Application of 5G Technology to Conduct Real-Time Teleretinal Laser Photocoagulation for the Treatment of Diabetic Retinopathy. JAMA Ophthalmology. 2021; 139(9):975–982. https://doi.org/10.1001/jamaophthalmol.2021.2312

99. De Lott LB, Newman-Casey PA, Lee PP, Ballouz D, Azzouz L, Cho J, et al. 2021. Change in Ophthalmic Clinicians' Attitudes Toward Telemedicine During the Coronavirus 2019 Pandemic. Telemedicine Journal and e-Health: the Official Journal of the American Telemedicine Association. 27(2):231–235. https

100. Li JO, Liu H, Ting D, Jeon S, Chan R, Kim JE, et al. Digital technology, tele-medicine and artificial intelligence in ophthalmology: A global perspective. Progress in Retinal and Eye Research. 2021; 82:100900. https://doi.org/10.1016/j.preteyeres.2020.100900

101. Pierce RP, Stevermer JJ. Disparities in the use of telehealth at the onset of the COVID-19 public health emergency. Journal of Telemedicine and Telecare. 2023; 29(1):3-9. doi:10.1177/1357633X20963893

102. Elam AR, Sidhom D, Ugoh P, Andrews CA, De Lott LB, Woodward MA, Lee PP, Newman-Casey PA. Disparities in Eye Care Utilization During the COVID-19 Pandemic. American Journal of Ophthalmology. 2022; 233:163–170. https://doi.org/10.1016/j.ajo.2021.07.024

103. Ung L, Chodosh J. COVID-19 and the eye: alternative facts The 2022 Bowman Club, David L. Easty lecture. BMJ Open Ophthalmology. 2022; 7(1):e001042. https://doi.org/10.1136/bmjophth-2022-001042.

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