

ARTICLE



A smartphone lens attachment improves the quality of referrals to eye casualty

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BACKGROUND/OBJECTIVES: In recent years, eye casualty clinics have seen significant increases in patient numbers with reduced capacity. COVID-19 has exacerbated this issue and demonstrated the potential of telemedicine as a solution. Our study evaluated the potential benefit of a smartphone-based lens attachment to improve the referral pathway for anterior segment related complaints in eye casualty.

SUBJECTS/METHODS: Fifty-four consecutive patients with anterior segment complaints were recruited. A questionnaire was completed with each patient to simulate the history from the point of referral. White light and cobalt blue photos were captured using a smartphone lens. The clinician reviewing the patient was asked to document the actual diagnosis and the appropriate timeframe within which they felt the patient could safely have been seen within; both with and without the option of management advice at the time of triage. The subsequent images and questionnaires were reviewed by a single consultant Ophthalmologist who was independent to the data collection process. The assessor was asked to make a diagnosis and management plan based upon the questionnaire ('History'), and the questionnaire with the photo ('History with Image'), as well as rate their clinical confidence on a 1–5 scale.

RESULTS: Diagnostic accuracy was significantly higher in "History with Image" (98.2%), when compared to "History" only (48.2%). "History with Image" prevented significantly more appointments when compared to "History" alone, at similar levels to retrospective clinic review. Preventable appointments were increased if clinical advice was possible. Timeframe of appointments between 'History with Image' and 'Clinic' appointments was similar. Clinical Confidence was significantly higher at 4.5 with 'History with Image' when compared to 2.37 with 'History Only'.

CONCLUSION: A low-cost smartphone lens attachment, alongside a standardised clinical questionnaire, can improve the referral pathway to the hospital eye service by reducing unnecessary appointments, while improving clinical confidence and diagnostic accuracy during triage. Further work to evaluate referral pathways, including the development of systems that allow for secure image transmission are needed to understand the feasibility for the widespread adoption of this technology.

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INTRODUCTION

Eye casualty clinics across the UK have seen significant increases in patient numbers in recent years, with clinics often running over their intended capacity [1]. A significant number of eye-casualty attendees are found not to have urgent ophthalmic issues once reviewed in clinic [2]. Previous studies that reviewed this issue reported inappropriate referrals as a contributing factor and recommended better training for non-ophthalmologists and standardised referral pathways [2].

Individuals without ophthalmic training can quickly capture high-quality magnified images of the anterior segment by using a smartphone with an attached imaging device [3]. This technology has already been shown to lead to more appropriate referrals to hospital eye services when used as part of the referral process

within the community [4]. Ophthalmologists have reported clinical confidence in using modern teleophthalmology for referrals and remote consultations [5].

This study aims to evaluate the potential benefit of a smartphone-based lens attachment to improve the triage process and patient pathway for anterior segment presentations to emergency eye care services.

MATERIAL AND METHODS

This study was completed in accordance with the ethical standards of the Helsinki Declaration of 1975 (as revised in 1983) and was approved by a local research and ethics committee at the Royal United Hospitals (RUH) Bath NHS Foundation Trust (Project ID 3532).

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Recruitment

Patients were prospectively recruited from the Eye Casualty clinics at the RUH in the period from March 2020 to June 2020. Inclusion criteria consisted of all patients with anterior segment complaints. There were no applicable exclusion criteria. Patients were asked if they wished to participate in the study, confirmed with written consent and then consecutively recruited in the above period. None of the eligible patients asked to take part in the study declined.

Data collection

Following consent, the clinician reviewing the patient completed a questionnaire that was adapted from the RUH 'Eye Casualty Triage Form' (Appendix 1). An iPhone SE (Apple, California, USA) was used with a smartphone lens attachment (Quickvue, Visuscience Ltd., Shanghai, China) and the Powerchart application (Cerner, Missouri, USA). Two photos were subsequently captured at ten times magnification, one with white illumination and one with cobalt blue illumination following 1% fluorescein instillation (Bausch & Lomb, Surrey, UK). Appendix 2 demonstrates images captured during the study.

Categorisation

The questionnaires and images were reviewed by a single Consultant Ophthalmologist who was blinded to the data collection process. The assessor made a diagnosis, firstly based on the questionnaire and subsequently, with the questionnaire with the photo.

The clinician reviewing the patient documented the number of days the patient could have safely waited to be seen in the Eye Casualty clinic from the point of referral, with the benefit of reviewing the patient and making the diagnosis.

Participants were classified into three groups for comparison, namely "History", "History with Image", and "Clinic". "History" is the group where the questionnaire alone was used to guide clinical decision making. "History with Image" is the group where the questionnaire and images were used. Clinic is the group where the patient was physically reviewed in clinic.

To simulate a referral scenario both the clinician who reviewed the patient in clinic and the assessor were asked to state for all patients if "Clinical Advice Was Possible" and "Clinical Advice Was Not Possible" what the outcome would be in terms of type of clinic appointment, and associated urgency (i.e. timeframe). Timeframe was defined as the number of days the patient could have safely waited to have been seen in clinic from point of referral. We defined clinical advice as being able to inform the referrer of the diagnosis and management plan and it being initiated on the day of referral. The blinded assessor was asked to document their confidence in their clinical decision making on a Lickert Scale (1–5) based upon 'History Only' and 'History with Image'.

Data analysis

All analyses were carried out using GraphPad Prism® 6 (GraphPad Software, California, USA) and SPSS® Statistics 23 (IBM, New York, USA). The Shapiro-Wilk test was performed to assess normality of data. Continuous variables are expressed as mean ± SD for normally distributed data and median (range) for those without a normal distribution, and compared using the independent samples *t*-test and Mann–Whitney *U*-test respectively. Clinical confidence was graded using a Lickert Scale with 1 being not confident at all and five being very confident. All statistical tests were two-sided, and $P < 0.05$ was considered as statistically significant. The data that support the findings of this study are available on request from the corresponding author [SM]. The data is not publicly available due to it containing information that could compromise research participant privacy/consent.

RESULTS

Fifty-four patients in total were included in the study with their demographics displayed in Table 1. Mean age was 59.2 ± 18.4 years (range 13–98). Referrals were primarily from General Practitioners (57.4%) and community optometrists (14.8%). A range of patient diagnoses were made in clinic and are displayed in Table 1.

The remote consultation outcomes were compared to the face-to-face clinical reviews, which were considered the gold standard.

Table 1. Demographics of study participants.

Age (years)	59.2 ± 18.4
Male (%)	20 (37)
Referral source (%)	
GP	31 (57.4)
Optician	8 (14.8)
Self-referral	7 (13)
ED	6 (11.1)
Inpatient	2 (3.7)
Diagnosis (%)	
Acute anterior uveitis	6 (11.1)
Dry eyes	4 (7.4)
Corneal abrasion	4 (7.4)
No pathology	3 (5.6)
Corneal ulcer (contact lens)	3 (5.6)
Viral conjunctivitis	3 (5.6)
Preseptal cellulitis	3 (5.6)
Marginal keratitis	2 (3.7)
Foreign body	2 (3.7)
Basal cell carcinoma	2 (3.7)
Sutures causing irritation	2 (3.7)
Subconjunctival haemorrhage	2 (3.7)
Blepharitis	2 (3.7)
Dermatochalasis	2 (3.7)
Corneal ulcer (neurotrophic)	1 (1.9)
Hyphaema	1 (1.9)
Corneal scar	1 (1.9)
Chemical injury	1 (1.9)
Dacryocystitis	1 (1.9)
Peripheral Ulcerative Keratitis	1 (1.9)
Ectropion	1 (1.9)
CN6 Palsy	1 (1.9)
Corneal ulcer (dendritic)	1 (1.9)
Lid laceration	1 (1.9)
HZV keratouveitis	1 (1.9)
Conjunctival inclusion cyst	1 (1.9)
Episcleritis	1 (1.9)
Trichiasis	1 (1.9)
Entropion	1 (1.9)

GP general practitioner, ED emergency department, CN6 cranial nerve 6, HZV herpes zoster virus.

Diagnostic accuracy of remote review with "History Only" was 48.2%, and "History with Image" was 98.2%. The difference observed in the number of accurate diagnoses made between "Clinic" and "History", and between "History" and "History with Image" were statistically significant (Fig. 1).

The number of potentially preventable eye casualty appointments was assessed. Where advice was not possible, preventable eye casualty appointments were 8 in the 'Clinic' group (14.8%), 1 in the 'History' group (1.9%, $P < 0.05$ when compared to "Clinic"), and 8 in the "History with Image" group (14.8%, ns when compared to "Clinic") (Fig. 2A). The number of patients referred to specialist clinics were: "Clinic" (9, 16.7%), "History" (13, 24%), "History with Image" (17, 31.5%). Where advice was possible, preventable eye casualty appointments were: "Clinic" (21, 38.9%),

"History Only" (10, 18.5%; $P < 0.05$ when compared to "Clinic"), "History with Image" (19, 35.2%; ns when compared to "Clinic") (Fig. 2B). The number of patients referred to specialist clinics were: "Clinic" (9, 16.7%), "History Only" (9, 16.7%), "History with Image" (12, 22.2%).

When we compared the number of preventable clinic appointments between if Advice Was/Was Not Possible, clinical advice was found to significantly reduce the number of non-necessary clinical appointments in all three categories ("Clinic", "History Only" and "History with Image"; $P < 0.05$).

We assessed whether there were any differences between the number of days patients could safely wait for an appointment between the groups, and the 'Actual' timeframe patients waited for. Some patients were excluded from this data set due to the clinician documenting that they did not require an eye casualty clinic appointment.

Where advice was not possible, the mean number of days that a patient could have safely waited from referral to eye casualty clinic were as follows: "Actual Timeframe" (1.3 ± 0.94), "Clinic"

(2.4 ± 2.02), "History" (4.4 ± 2.87), "History with Image" (3.1 ± 2.71 ; Fig. 3A). The number of days for "Clinic", "History" and "History with Image" were individually compared with the "Actual Timeframe" mean number of days and found to have significantly higher means. The mean number of days in "History" was found to be a statistically significant higher mean when individually compared with both "Clinic" and "History with Image" ($p < 0.05$). When comparing the mean number of days between "Clinic" and "History with Image" there was no statistical difference.

Where advice was possible, the mean number of days that a patient could have safely waited from referral to eye casualty clinic were as follows: "Actual Timeframe" (1.3 ± 0.94), "Clinic" (1.8 ± 2.34), "History" (4.8 ± 2.84), "History with Image" (2.3 ± 2.72 ; Fig. 3B). Similarly, to the "advice not possible group", the mean number of days in "Actual Timeframe" were significantly lower when compared to the other groups. The mean number of days in "History" was found to be statistically significantly higher when compared with both "Clinic" and "History with Image". There was no statistically significant difference between "Clinic" and "History with Image".

When we compared the mean timeframe for clinic appointments against if clinical advice Was/Was not possible, clinical advice did not significantly impact the mean timeframe in all three categories ("Clinic", "History Only" and "History with Image").

Clinical confidence for decision-making was graded 1–5 for the "History" and "History with Image" groups. Clinical confidence was significantly higher ($P < 0.05$) in the "History with Image" group (4.5 ± 0.66), when compared to the "History" group (2.37 ± 0.96), see Fig. 4.

DISCUSSION

This study shows that a smartphone lens attachment (as shown in Appendix 3), alongside a standard clinical questionnaire, can reduce unnecessary appointments to Eye Casualty, while improving clinical confidence and diagnostic accuracy during triage.

Our study's patient demographics, breath of diagnoses and referral sources are comparable to the published literature [1, 2, 6].

Our study demonstrated a diagnostic accuracy of 98.2% when the smartphone lens attachment was used alongside the clinical history and thus provides strong evidence for its use alongside referrals. With the history alone, which is representative of a typical referral, the diagnostic accuracy was reduced to 48.2%. This level of diagnostic accuracy from the history alone from referrals has been observed in other studies and stresses the importance of objective visual assessment, either through slit-lamp examination or digital photography as in our study [7]. Previous research has referred to limitations of anterior segment tele-ophthalmology, including poor image quality and the inability to adequately assess corneal conditions [8]. The lens used in this study allowed

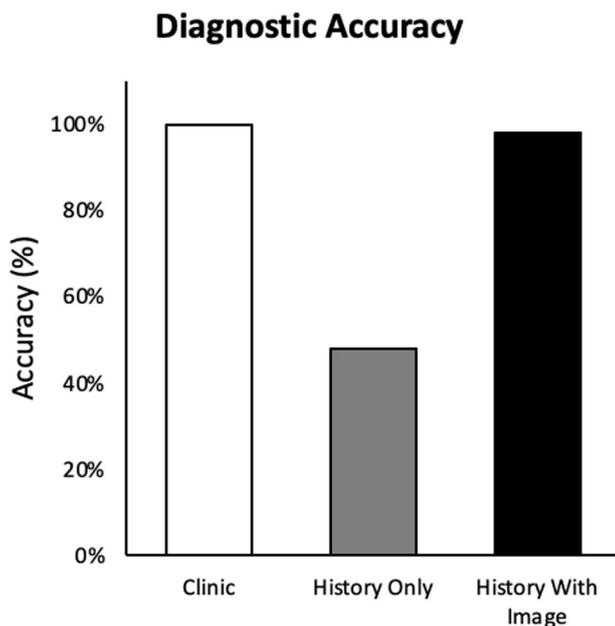


Fig. 1 Diagnostic accuracy. Diagnostic accuracy was observed as follows; "Clinic" (100%), "History Only" (48.2%) and "History with Image" (98.2%). The difference observed in the number of accurate diagnoses made between "Clinic" and "History Only" and between "History Only" and "History with Image" were found to be statistically significant.

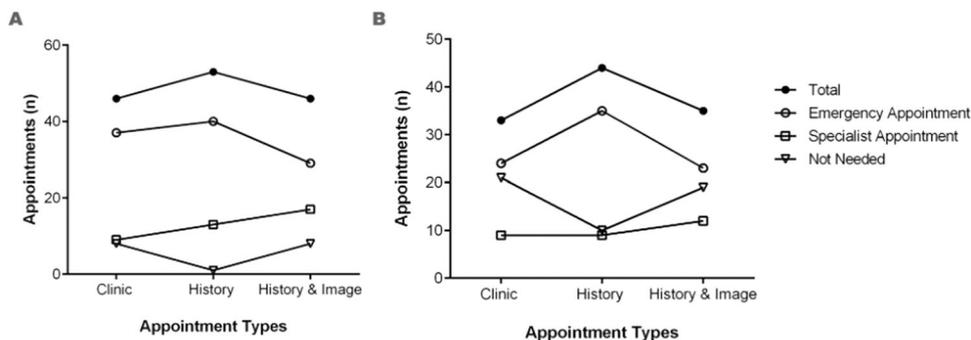


Fig. 2 Preventable emergency appointments. **A** When advice was not possible, "Clinic" and "History with Image" review prevented 14.8% of appointments, while "History" prevented only 1.9% of appointments ($P < 0.05$). **B** When advice was possible, "Clinic and History" with Image review prevented ~37% of appointments, while "History" prevented only 18.5% of appointments ($P < 0.05$).

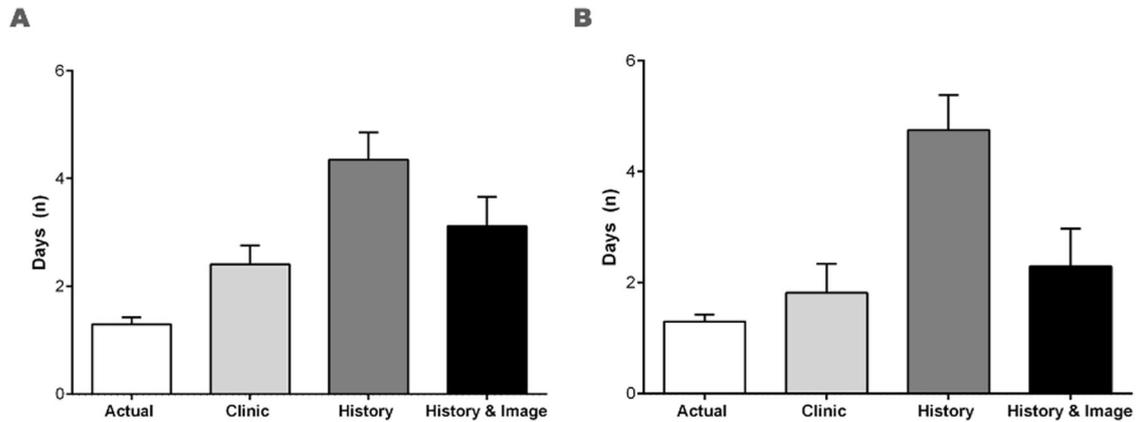


Fig. 3 Timeframe from referral to clinic. A Timeframe that patients could have safely waited from referral to clinic if advice was not possible. The Actual timeframe (1.3 ± 0.94 days) was significantly shorter to all groups. "Clinic" (2.4 ± 2.02) and "History with Image" (3.1 ± 2.71) had no statistical difference, while "History" (4.4 ± 2.87) group significantly increased the number of days when compared to all groups. **B** Timeframe that patients could have safely waited from referral to clinic if advice was possible. The Actual timeframe (1.3 ± 0.94 days) was significantly shorter to all groups. "Clinic" (1.8 ± 2.34) and "History with Image" (2.3 ± 2.72) had no statistical difference, while "History" (4.8 ± 2.84) group significantly increased the number of days when compared to all groups. Error bars represent standard error.

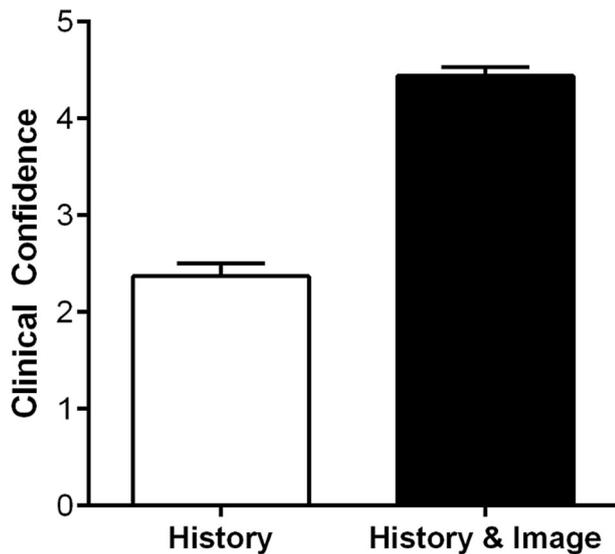


Fig. 4 Clinical confidence. Clinical confidence between "History Only" (2.37 ± 0.13), "History with Image" (4.5 ± 0.09) which was statistically significant. Error bars represent standard error.

for 10x magnification in both white and cobalt blue illumination, factors which go some way towards overcoming previously described limitations.

Our data shows that referrals with clinical images lead to a significant reduction in eye casualty clinic appointments when compared with the history from referrals alone. This was observed in both categories of being/not being able to give clinical advice and is likely to be explained by the identification of physiological variants or non-acute diagnoses, such as dry eyes. When comparing the appointment distribution between 'Clinic' and 'History with Image', they demonstrated similar patterns but with the advantage to the patient of not having to physically attend the clinic. Tele-ophthalmology has the potential to offer clear and timely advantages to the patient during the COVID-19 pandemic and beyond, while reducing the burden on clinic appointment resources [3]. The trend of reduced appointments with 'Clinic' and 'History with Image' is likely due to the higher diagnostic accuracy observed in these two categories. This observation of more

appropriate clinic appointments with the use of tele-ophthalmology as part of referrals to hospital eye services has previously been demonstrated [6]. When the clinician was able to give clinical advice to the referrer at the point of referral this was found to significantly reduce non-necessary appointments in all three categories, demonstrating the importance of starting early treatment for common anterior segment pathologies.

When comparing the mean timeframe patients could have safely waited from point of referral to attending the eye casualty clinic, 'Clinic' and 'History with Image' had comparable data. Of note, 'History Only' had a significantly longer mean timeframe than compared with both 'Clinic' and 'History with Image'. This result was not expected and may be due to more patients being included within the 'History Only' sub-group that may have increased the mean timeframe, as both 'Clinic' and 'History with Image' had more patients excluded for comparison due to non-necessary or specialist appointments. Another reason for this may be that 'History Only' had significantly less diagnostic accuracy and thus is more likely to have included the non-pathological or non-urgent ophthalmic conditions, which has been widely reported to make up a significant proportion of referrals to eye casualty [2]. Thus, the shorter mean timeframe observed in both 'Clinic' and 'History with Image' is likely to actually represent the patients that require urgent review.

We observed no statistical difference if the clinician was/was not able to give clinical advice to the referrer at point of referral and the mean timeframe of referral in all three categories ("Clinic", "History Only" and "History with Image"). As clinical advice did have a significant impact on appointment distribution, it suggests clinical advice has more of an influence on if the patient does/does not need to be seen in eye casualty, rather than how soon the patient needs to be seen in eye casualty. This may again be due to the type of diagnoses that do require seeing in eye casualty, as regardless of timely commencement of treatment, they will need to be reviewed in clinic shortly from the referral. Furthermore, some of the conditions may not have initial treatments altogether, or treatments that can be given in the community, and thus require urgent clinic review.

The clinical confidence of the assessor was significantly greater when using "History with Image" then compared with "History Only". This again illustrates the importance of the physical examination, or another reliable and reproducible tele-ophthalmic method in clinical ophthalmology. Our study provides further evidence that tele-ophthalmology can provide clinical confidence, which has been demonstrated in other studies [7].

Our study has several limitations, including the assumption that the diagnosis was correct when the patient was initially reviewed in clinic, however, the reproducible diagnostic accuracy with 'History with Image' makes this less likely. Our study used one ophthalmology consultant as the assessor, which may reduce reliability. When comparing the 'Clinic' outcomes compared with the assessor's outcome, there was a variety of ophthalmology clinicians making the initial review, compared with one consultant assessing after and thus does not make for a complete like-for-like comparison.

Our study has demonstrated that a simple, low-cost smartphone lens attachment can provide high quality imaging and diagnostic accuracy that has the potential to improve the referral pathway to the hospital eye service. The need to reduce non-necessary clinic appointments and optimise the triage process for eye casualty referrals is paramount, particularly in a time where fewer appointments are available to patients as a result of the COVID-19 pandemic. Further work to evaluate referral pathways, including the development of systems that allow for secure image transmission are needed to understand the feasibility of widespread adoption of this technology.

SUMMARY

What was known before

- Emergency eye care services are under considerable strain with higher numbers of patients and reduced capacity. A significant proportion of patients attending eye casualty clinics do not have pathology requiring face to face clinical review Smartphone based technology has significant potential in tele-ophthalmology.

What this study adds

- Smartphone lens attachments are able to capture images of sufficient quality to be able to accurately and safely reach diagnoses and aid in the triage process for emergency eye care services.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author [SM]. The data is not publicly available due to it containing information that could compromise research participant privacy/consent.

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AUTHOR CONTRIBUTIONS

SM, OR, PM, JC, JB and JL planned the study design, completed the data collection, analysis and interpretation. SM, OR, JC, AK, AC, PM, JB and JK co-authored the article and approved the final version of the manuscript.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

Supplementary information The online version contains supplementary material available at <https://doi.org/10.1038/s41433-022-02233-w>.

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