



The Scope of Eye Tracking and Dental Education - A Review

Chandrasekharan Nair K^{1*}, Viswanath Gurumurthy²,
Pradeep C Dathan³, T Mohan Kumar⁴ and Vivek V Nair⁵

¹Professor Emeritus, Department of Prosthodontics, Sri Sankara Dental College, Akathumuri, Thiruvananthapuram, Kerala, India

²Associate Professor, Department of Dental Technology, College of Applied Medical Sciences, King Khalid University, KSA

³Professor and Head of the Department of Prosthodontics, Sri Sankara Dental College, Akathumuri, Thiruvananthapuram, Kerala, India

⁴Director, Centre for Temporomandibular Disorders, Kunnukuzhi, Trivandrum, Kerala, India

⁵Professor of Prosthodontics, Government Dental College, Trivandrum, India

***Corresponding Author:** Chandrasekharan Nair K, Professor Emeritus, Department of Prosthodontics, Sri Sankara Dental College, Akathumuri, Thiruvananthapuram, Kerala, India.

Scopus id: <https://orcid.org/0000-0003-3114-3015>

Received: September 02, 2025

Published: October 13, 2025

© All rights are reserved by

Chandrasekharan Nair K, et al.

Abstract

Eye tracking is a versatile research tool that can provide a profound understanding of the cognitive profile of health care providers, patients and individuals who frequently use medical devices. Generally, it is considered that eye tracking is in the evolving stage. Dentistry has a streamlined educational process that includes well designed clinical training programmes. Experienced professionals have immensely contributed towards this with the assistance of sophisticated techniques like eye tracking. This review narrates the early history of eye tracking and has included brief descriptions of various application fields related to eye tracking.

Keywords: Eye tracking, early history of eye tracking, dental education, website testing, driving research, fixation, saccades

Introduction

Eye tracking is considered as a modern research tool but its roots can be traced back to 19th century. A French ophthalmologist - Javal L E initiated the studies on eye movements that happen during reading (Figure 1). He has observed in 1879 that continuous movement of the eye along the line of text is not required for reading. The reading process consists of short rapid movements (saccades) intermingled with short stops (fixations). Huey E is consid-

ered as the first creator of an eye tracker (1898). He used a contact lens like device which had an opening in front of the pupil. This was an invasive procedure and Huey had to give cocaine to reduce the discomfort of the subjects. The lens had an attached pointer which moved along with the eye movement [1,2]. (Figure 2).

Delabarre E B also tried a similar invasive method. A cap made of gypsum was positioned on the wet surface of the eye. The cap had a

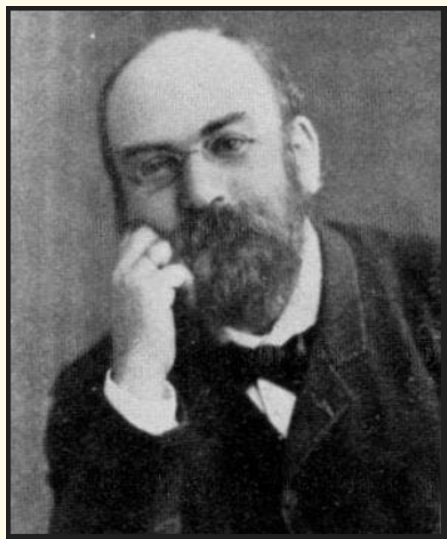


Figure 1: Javal L E who initiated the studies on eye tracking.



Figure 2: Edmund Huey, the creator of first eye tracker.

hole through which the subject could read. A wire was attached to the cap and which in turn was connected to a lever capable of drawing horizontal movements on a sooted cinematographic cylinder. Delabarre himself was the subject of experiment and anaesthetized

the eye with Cocaine. The experiment lasted for an hour and the recovery from anesthesia happened in a week's time [3].

In 1901, Dodge A R and Cline T S developed the first non-invasive optical eye tracker on which light was allowed to fall on the cornea and got it reflected which passed through an optical system and recorded the eye movement on a photosensitive plate. Only horizontal movements were recorded and the subjects had to keep the head still [4]. Both horizontal and vertical movements were recorded by Judd et al. They fixed a mechanical indicator on the eye which reflected a light spot on to a photosensitive tape. The test subject has to keep the head stationary [5]. In 1935 Buswell created a non-contact device to register eye movements. He focused on studying the difference between reading and watching images. Light that got reflected from cornea enabled two-dimensional registration of single eye movements. Buswell observed that there is a difference between oral and silent reading. He has stated that colour has little effect on eye movement [6,7].

'*Eye Movements and Vision*' by Yarbus A L is a landmark work on visual neuroscience that explored eye movements and its relationship with human perception. This book was published originally in Russian in 1965 and it got translated into English. The book presents the pioneering experiments of Yarbus using a suction-cup eye-tracking device. Through meticulous observations, Yarbus demonstrated that eye movements are closely related to the viewer's cognitive tasks and intentions. His most famous experiment showed that when participants were asked different questions while viewing a painting named '*The Unexpected Visitor*' (Figure 3), their gaze patterns changed based on what they were instructed to look for-highlighting the role of top-down processes in vision. He has also observed that when different individuals were shown the same painting, the pattern of eye movements were similar, however the movements were not identical. When the painting was repeatedly shown to the individual with an interval of few days, the pattern of eye movements was similar. When an individual observes the photograph of face, a cyclic behaviour was found. The observation cycle moves in a triangular pattern connecting both the eyes and the nose/mouth. It was established that observers were first attracted to look at the eyes. When the face is looked at for long periods, repeated cycles connecting key features of face viz. eyes, nose and mouth were made. However, the cyclic viewing of face with the body included in the photograph did not remain

similar [8]. In the 1960s, a device by name Oculometer was made for the US Airforce which had a design almost similar to the modern counterparts [9-11].



Figure 3: The unexpected visitors.

Rayner in 1998, consolidated the knowledge obtained from the research that has taken place between 1970 to 1990 and it was entitled 'Eye movements in reading and information process'. This period was followed by computer operations and electronic data processing. Till the year 2000, eye gaze research hovered around academic subjects like physiology, psychology and ophthalmology. The research was mainly aimed at the working pattern of eyes and the method of information processing that occurred consciously or unconsciously [12]. Eye tracking analysis found great developments along with the rise of computer applications. The first two decades of the present century witnessed a phenomenal rise in the IT industry and portable eye trackers have increasingly become popular [13].

Popular eye tracking techniques

Some of the popular eye tracking techniques used in the initial evolutionary stages were:

- Electrooculography (EOG)
- Scleral search coils
- Video-based pupil monitoring

- Infrared corneal reflection
- **Electro oculography (EOG):** is used to measure the electrical potential difference between cornea and retina of the eye. EOG is based on the principle that eye ball is electrically charged. When the eye moves, the potential difference, changes and this information is used to track the eye movements. Electrodes are positioned around the eye which can measure the changes in potential difference (Figure 4). EOG is used for research related to diagnosis of eye diseases, eye movements and controlling devices like wheel chairs that are managed with eye movements. EOG signals can be used to operate computer-controlled devices and it is of great help for people with mobility limitations.



Figure 4: Electro oculo graphy.

- **Scleral search coils (SSC):** This is an invasive method and measures the voltages induced by magnetic fields. The coils are directly connected to the sclera or to a contact lens. Coils induce voltage when exposed to a magnetic field and it helps in tracking eye movements. Movement of the eye is affected by the functioning of coils and hence the duration of use is limited to 30 minutes.
- **Video based pupil monitoring:** Is done by video camera and it determines where exactly a person looks at (Gaze) and analyses the pupil behaviour like changes in the diameter. Video cameras are either mounted on a head set or positioned remotely. The pupil and the reflection from a light source (infra-red) are analysed by the algorithms. Pupil size can indicate cognitive load, emotional status and levels of arousal. Fatigue levels of vehicle drivers are diagnosed by this method. This can also be used to diagnose diseases (Figure 5).

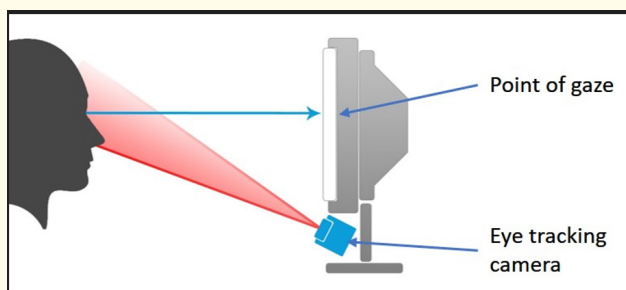


Figure 5: Eye tracking and gaze point.

- **Infrared corneal reflection:** This method analyses eye movements. Infra-red is used to make a reflection from the cornea (Figure 6). The movement of reflections can determine where exactly a person looks at, how long that person sustains and along with that the pupil size. Infrared is superior to visible light and pupil centre corneal reflection is easily achieved [14,15].

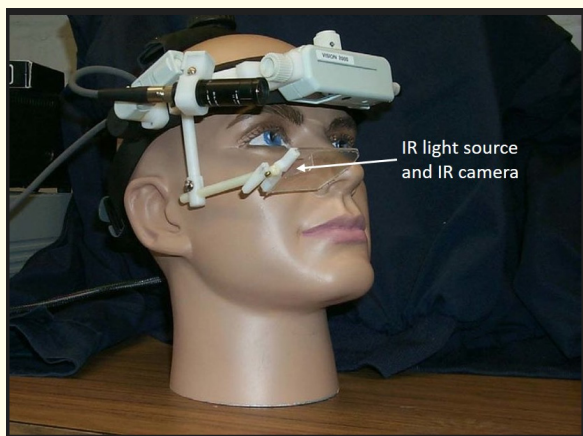


Figure 6: Infrared eye tracking system.

Presently used eye tracking systems

Three different eye tracking systems are employed presently - 1. Screen based 2. Glasses based (mobile) and 3. Tracking systems integrated to Virtual Reality (VR) headsets.

Screen based eye trackers are used in laboratories to analyse gaze on websites, videos and physical objects. This system utilises infrared lights and cameras to monitor pupil and reflections from cornea. Eye tracker is positioned at a distance from the respondent and close to a computer or screen (Figure 7).



Figure 7: Screen based eye tracking system. Fixation points and saccades are also shown.

Mobile trackers are designed to be worn as spectacles (glasses). It can be used in natural dynamic situations like social interactions and in public spaces. Eye activities are recorded from a close range in any real life or virtual environment for product testing and usability testing (Figure 8).



Figure 8: Eye tracking spectacles.

Eye trackers are integrated to virtual reality (VR) and augmented reality (AR) headsets. Usually, gaze is tracked within a simulated environment (Figure 9).



Figure 9: Eye tracking integrated to Virtual Reality headset.

Some organisations make eye trackers available in the market under the following brand names: Tobii, SMI Vision, Eye Link, Imotions, Mirametrix and Eye Tech [16].

Commonly used terms related to eye tracking

- **Eye tracking:** Eye tracking is a technology that measures the eye movements and determines where a person is looking at and its duration. Measurement of pupil size is also included in this.
- **Gaze point:** The specific point on a screen (picture) or in a visual field where the eye gets focused.
- **Fixation:** Brief pauses, the eye makes when it focuses on a specific point. At this point the eyes are relatively stationary and collect information from the object of focus. Fixations may last between 100 - 600 milliseconds. Variations can happen depending upon the task and the stimuli.
- **Saccades:** Both the eyes move rapidly between fixation points in the same direction. The movement is rapid and jerky. Saccades last for 20 - 80 milliseconds.
- **Pupil dilation:** This refers to widening of the pupil. Under low lighting conditions pupils dilate to allow more light to reach the retina. Strong emotions and fear can trigger dilation of pupils. When the cognitive load increases (brain works more as in memory tasks or in driving), pupil dilates.

- **Field of view:** The extent of observable space or area within which eye movements are recorded.

Why should we do eye tracking

Eye tracking is done to gain insights into human behaviour, cognition, and visual perception by measuring gaze patterns, fixations, and saccades. This is a non-invasive system which helps to improve product design and user experience, understand customer preferences and decision-making. Eye tracking can diagnose learning disabilities like dyslexia, analyse medical procedures, enhance driver and worker safety. Eye tracking is also performed in advanced scientific research across various fields like psychology, neuroscience, education and human-computer interaction [17].

Application of eye tracking in dental education

Dental education has always incorporated a visual element in both teaching and learning. Proficient clinicians and dental students have different gaze patterns. Experienced clinicians opt for short duration of fixation and their scanning is limited to focused areas. Dental students opt for prolonged gaze which is very often scattered. While a clinician focuses on critical areas quickly, a student might miss those areas or takes a long time to focus on critical areas. Preparation of teeth, obtaining endodontic access and interpretation of radiographic information are some of the assessment situations where eye tracking can be of great help. Eye tracking also serves as a teaching/learning tool in evaluating behavioural status of the patient and students can evaluate patient's response to communication. Information obtained from eye tracking enables the students to understand key concepts quickly along with improvement in visual attention. Eye tracking can provide information on where exactly the student is lacking focus during the performance of a clinical skill. Skill training that integrates eye tracking can help the student learn effectively and efficiently [18-20].

Role of eye tracking in clinical training of dentistry

When a student performs a clinical step, if eye tracking is done, the instructor can identify where exactly the student is focusing and which are the areas where the student is struggling. Teacher can immediately give correctional feedback and which helps the student in refining precision in procedures and enhancing accuracy in diagnostics. When the instructor understands the student's visual attention pattern, the training system can be modified to improve learning effectiveness. If the gaze patterns of experienced profes-

sionals are understood and if the trainee can follow that, diagnostic accuracy can be enhanced. Eye tracking can guide the students to adopt better skills.

If the gaze patterns of experienced dentists, if followed, especially in virtual training environments, students' efficiency will definitely improve. If eye tracking patterns of children, while making a visit to the dentist, are understood by the dentist, dentist patient relation can be established easily and which will lead to a strong communication link. By the tracking of eye movements, scientists can get insights into the behavioural details while performing a procedure like examination of radiographs and treatment planning [21].

Eye tracking and interpretation of clinical images

Muthu et al. have evaluated the gaze behaviour of dental students using clinical photographs and correlated it to the diagnostic competence. Images were shown on a screen and while the participants were evaluating, their eye movements were tracked by Tobii Pro Nano device. The authors observed that the average view time was 190 seconds. Majority of the participants were attracted to the centre of the image. The viewing sequence followed by a large number of the participants were of 'Z' pattern - left to right. Participants were attracted to the centre (fixation) and then the movements were not following a systematic pattern. The diagnostic competence could not get a positive correlation with eye tracking. The authors have suggested further studies to come to a definite conclusion. Eye tracking will definitely enhance training patterns in dentistry [22]. Yamamoto et al. have analysed gaze points using lay persons who were instructed to observe mouth images which contained non aesthetic restorations. Attention of the participants were attracted to the non aesthetic restorations when compared to the normal side. Non aesthetic side was gazed longer than the opposite normal side. Even lay persons could correctly recognise non aesthetic restorations and this cautions dental professionals on the importance of providing restorations with high quality aesthetics [23].

Radiographic assessment

Analysis of radiographs using eye tracking method can bring in optimising factors like diagnostic accuracy, identifying error sources and understanding inaccurate gaze patterns. Eye tracking can reveal how a dentist and a dental student observe an image, finds out the differences in gaze patterns, fixations and saccades. Eye tracking can find out the areas where the dentists' attention is lacking and

where misinterpretations occur. Saccades - the quick movements that happen between fixations as well as pupil dilatation are also recorded. The information obtained thereby can help the trainees in systematising the reading of radiographs. Missing of vital points can be avoided by employing the information obtained through eye tracking. It has generally been observed that an experienced person can arrive at the fixation point quickly than an inexperienced counterpart. The metrics shows that an increase in experience concurrently increases the duration of fixation and the distance between the fixations also increase. Eye tracking information provides its usefulness as a training tool [24].

Prostho preclinical evaluation

Silvestri et al. have evaluated the gaze behaviour during tooth preparation, of two sets of dental professionals viz. experts and novices. Experts had in an average 19 years of experience and the novices were third year dental students. Eye tracking metrics like total duration of fixation (TDF), number of fixations (NF), time taken to locate the first fixation (TFF) and pupil size were measured. The measurements were conducted on different areas of interest (AOI). The AOI of both experts and novices was on the buccal wall and the finish line of tooth preparation. Novices took more time on fixation; they had more frequent fixations and for the novices there was a delay in arriving at the first fixation. Experienced professionals take lesser time in executing the skill. The eye tracking metrics provide information on efficient gaze patterns to be adopted and this can be used in the training system. Faster learning can happen by employing the eye tracking information collected from experts [25].

Eye tracking in medical practice

Eye tracking has provided promising insights into the diagnosis of various medical conditions belonging to ophthalmology and neurology - attention deficit hyper activity disorder (ADHD) and autism spectrum disorder (ASD). In ophthalmology, the following conditions are diagnosed: glaucoma, macular degeneration and diabetic retinopathy. Eye tracking is efficient in diagnosing myasthenia gravis and it serves as a diagnostic tool for Parkinson's disease and Alzheimer's disease. Reduced saccadic velocity is considered as a biomarker for Parkinson's and Alzheimer's.

Medical training and research get refined with eye tracking. Experienced professionals like cardiologists have a unique eye movement pattern like short fixation time, frequent saccades and focused

scan routes. If this strategy is identified and employed in the training programme, it can foster acquisition of expertise effectively. Eye tracking improves treatment outcomes in the areas of cognitive and visual rehabilitation. Computerised eye tracking system can be used for voiceless communication. Other than the usefulness in clinical practice, patient care and research, eye tracking can also provide insights into the intricacies of human behaviour and cognitive characteristics [26].

Discussion and Conclusions

Eye tracking has been widely used for several decades, particularly in experimental psychology. However, its application in health care research and medical device evaluation remains at an early stage of development. Eye tracking provides valuable insights into the cognitive processes of health care providers, patients, and medical device users. Central to this field is the eye-mind hypothesis, which posits a strong relationship between visual fixation (what one is looking at) and attention focus (what they pay attention to). This principle has been applied in various contexts, such as studying attention allocation in clinicians, investigating autism spectrum disorder (ASD), and examining physiological correlates of cognition through metrics like pupil dilation and blink rate [27,28].

Early eye-tracking systems were intrusive and required complex procedures. Modern devices, in contrast, are non-invasive, remote, and often wearable. They commonly employ near-infrared technology to capture pupil-corneal reflections, with cameras tracking these reflections to infer gaze behaviour.

The versatility of eye tracking has paved the way to its adoption across diverse domains

- **Neuroscience and psychology** - to analyse gaze patterns, thereby revealing underlying cognitive processes such as learning, memory, and attention. Deviations in gaze behaviour can serve as diagnostic indicators.
- **Medical and dental education** - to compare gaze strategies of experts and novices, enabling the design of more effective training programs.
- **Market research** - to get an insight into the consumer behaviour and the factors that influence the product appeal.
- **Driving and transportation research** - to study driver attention and distraction, particularly in high-risk scenarios such as the use of mobile phones.

- **Education** - to examine student attention, information encoding and memory retrieval strategies. Eye tracking provides objective measures that verbal reports cannot capture, offering insights into classroom engagement, slide scanning behaviours, and note-taking strategies.
- **Web and interface usability testing** - to evaluate viewing patterns, advertisement impact, and presentation effectiveness [29].

Careful integration of eye-tracking methodologies into dental educational systems could substantially enhance the effectiveness of clinical training programmes. Eye-tracking metrics may soon become an essential component in evaluating attention and the learning processes of dental students, thereby advancing both learning capabilities and patient care.

Conflict of Interest

The authors declare that they do not have any conflict of interest.

Author Contributions

Conceptualization-K. Chandrasekharan Nair; Review of articles-Viswanath Gurumurthy, Pradeep Dathan; Initial draft preparation: Viswanath Gurumurthy, Pradeep Dathan, Vivek V Nair; Review and editing- K. Chandrasekharan Nair, Mohan Kumar; Supervision-K. Chandrasekharan Nair.

All the authors have read and agreed to the published version of the manuscript.

Bibliography

1. Javal LÉ. "Essai sur la physiologie de la lecture". In: "Annales d'Oculistique" 82 (1879): 242-253.
2. Huey EB. "Preliminary Experiments in the Physiology and Psychology of Reading". In: "American Journal of Psychology" 9 (1898): 575-586.
3. Delabarre EB. "A Method of Recording Eye-movements". In: "Psychological Review" 8 (1898): 572-74.
4. Dodge AR and Cline TS. "The Angle Velocity of Eye Movements". In: "Psychological Review" 8 (1901): 145-157.

5. Judd CH., *et al.* "General introduction to a series of studies of eye movements by means of kinetoscopic photographs". In: J.M. Baldwin/ H.C. Warren/ C.H. Judd (eds.), *Psychological Review*, Monograph Supplements. Baltimore (1905): 1-16.
6. Buswell GT. "How People Look at Pictures". A study on the psychology and perception in art, Univ Chicago Press (1935).
7. Buswell GT. "How Adults Read". Supplementary Educational monograph series, University of Chicago (1937).
8. Tatler BW., *et al.* "Yarbus eye movements and vision". *I-perception* 1 (2010): 7-27.
9. Merchant J. "Interim Technical Report. Oculometer". Contract No. NASW-1159 (1966).
10. Merchant J., *et al.* "Remote Measurement of Eye Direction Allowing Subject Motion over One Cubic Foot of Space". In: "IEEE Transactions on Biomedical Engineering" 21.4 (1974): 309-317.
11. Monika PŁUŻYCZKA. "The First Hundred Years: a History of Eye Tracking as a Research". *Applied Linguistics Papers* 25.4 (2018): 101-116.
12. Rayner K. "Eye Movements in Reading and Information Processing: 20 Years of Research". *Psychological Bulletin* 124.3 (1998): 372-422.
13. <https://medium.com/@cybrain/gaze-based-interaction-30-years-in-retrospect-and-future-outlook-af923a32a921>
14. Ignace Hooge AL., *et al.* "The pupil is faster than the corneal reflection (CR): Are video based pupil-CR eye trackers suitable for studying detailed dynamics of eye movements?" *Vision Research* 128 (2016): 6-18.
15. <https://www.sr-research.com/about-eye-tracking/>
16. Punde P., *et al.* "A study of eye tracking technology and its applications" (2017).
17. <https://www.hotjar.com/conversion-rate-optimization/glossary/eye-tracking/>
18. Tahri Sqalli M., *et al.* "Eye tracking technology in medical practice: a perspective on its diverse applications". *Frontiers in Medical Technology* 5 (2023): 1253001.
19. Bhadila GY., *et al.* "Visual analysis of panoramic radiographs among pediatric dental residents using eye-tracking technology: a cross-sectional study". *Children (Basel)* 10 (2023): 1476.
20. Gnanasekaran F., *et al.* "Visual interpretation of panoramic radiographs in dental students using eye-tracking technology". *Journal of Dental Education* 86 (2022): 887-892.
21. Rangoli Srivastava and Surbhi Priyadarshi. "Eyes on the future: Navigating dentistry's revolution with eye tracking technology". *International Dental Journal of Student's Research* 12.2 (2024): 69-73.
22. Muthu MS., *et al.* "Visual interpretation of clinical images among dental students using eye-tracking technology". *Journal of Dental Education* 88 (2024): 606-613.
23. Yamamoto M., *et al.* "Analysis of gaze points for mouth images using an eye tracking system". *Journal of Prosthodontic Research* 61 (2017) 379-386.
24. Arthur E and Sun Z. "The Application of Eye-Tracking Technology in the Assessment of Radiology Practices: A Systematic Review". *Applied Sciences* 12 (2022): 8267.
25. Silvestri., *et al.* "Eye-tracking metrics to compare visual attention in prosthodontic preclinical evaluations". *BMC Oral Health* 25 (2025): 1350.
26. Tahri Sqalli M., *et al.* "Eye tracking technology in medical practice: a perspective on its diverse applications". *Frontiers in Medical Technology* 5 (2023): 1253001.
27. Asan O and Yang Y. "Using eye trackers for usability evaluation of health information technology: A systematic literature review". *JMIR Human Factors* 2.1 (2015): e4062.
28. Carter BT and Luke SG. "Best practices in eye tracking research". *International Journal of Psychophysiology* 155 (2020): 49-62 .
29. <https://openai.com/index/chatgpt/>