Looking at Plastic Surgery through Google Glass: Part 1. Systematic Review of Google Glass Evidence and the First Plastic Surgical Procedures

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Background: Google Glass has the potential to become a ubiquitous and translational technological tool within clinical plastic surgery. Google Glass allows clinicians to remotely view patient notes, laboratory results, and imaging; training can be augmented via streamed expert master classes; and patient safety can be improved by remote advice from a senior colleague. This systematic review identified and appraised every Google Glass publication relevant to plastic surgery and describes the first plastic surgical procedures recorded using Google Glass.
Methods: A systematic review was performed using PubMed National Center for Biotechnology Information, Ovid MEDLINE, and the Cochrane Central Register of Controlled Trials, following modified Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. Key search terms "Google" and "Glass" identified mutually inclusive publications that were screened for inclusion.
Results: Eighty-two publications were identified, with 21 included for review. Google Glass publications were formal articles ($n = 3$), editorial/commentary articles ($n = 7$), conference proceedings ($n = 1$), news reports ($n = 3$), and online articles ($n = 7$). Data support Google Glass' positive impact on health care delivery, clinical training, medical documentation, and patient safety. Concerns exist regarding patient confidentiality, technical issues, and limited software. The first plastic surgical procedure performed using Google Glass was a blepharoplasty on October 29, 2013.
Conclusions: Google Glass is an exciting translational technology with the potential to positively impact health care delivery, medical documentation, surgical training, and patient safety. Further high-quality scientific research is required to formally appraise Google Glass in the clinical setting. (*Plast. Reconstr. Surg.* 135: 918, 2015.)

Google Glass (Google, Inc., Mountain View, Calif.) is an exciting technology, attracting global interest from multiple industries, professions, and individuals. Plastic surgery thrives on innovation and has a history of embracing novel concepts, techniques, and technology to advance the speciality.[1,2] Google Glass,

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often abbreviated to "Glass," is ideally positioned to revolutionize clinical practice, surgical training, and audiovisual medical records for the contemporary plastic surgeon. This systematic review appraises the evidence for and against Google Glass application within medicine, science, and plastic surgery, and highlights the first plastic surgical procedures recorded using Glass by the senior author (L.K.R.).

By wearing Google Glass, the user controls the device using voice commands, touch, and head position. Live surgery can be recorded from a first-person perspective and streamed to a remote audience, permitting dialogue between surgeon and observers. Glass allows contemporary clinicians to read patient records, access investigations, and view imaging by means of the prism situated in the corner of the device (Fig. 1). The user may execute tasks by verbally addressing the device as "Glass," followed by the desired instruction. Further control is achieved by means of the touch-sensitive frame and a technological proprioceptive response from tilting of the head.

Sterility in the operating room is maintained by verbal control, allowing both hands to operate as normal, and the view of the operative field is unimpeded by the peripherally positioned prism. If desired, a portion of a standard sterile plastic drape (e.g., 3M 1010 Steri-Drape; 3M, St. Paul, Minn.) can be used to cover the right temple/arm of Glass to allow aseptic touch access. Glass can be fitted with prescription lenses and differing frame styles, and can provide eye protection in the operating room.[3,4] Sound is recorded and transmitted by means of a mastoid bone conductor and earpiece, allowing dialogue between surgeon and audience. Photographic images and videos can be taken for medical records or live-streamed for teaching or advice from a senior colleague.

Despite numerous potential advantages and the technological promise of Glass in the plastic surgical setting, critics may have reservations in terms of cost, confidentiality concerns, or medicolegal repercussions. This systematic review aims to identify and critique all medical and scientific literature associated with Google Glass and provide a balanced summary of its application within plastic surgery. In addition, a chronology of Google Glass introductions within surgery is provided, as are citations of early plastic surgical procedures recorded using Google Glass.

METHODS

To maximize the quality of this systematic review, modified Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines were followed.[5] This allows standardized, reproducible, and transparent documentation of search strategy and article selection. Multiple search facilities were used as outlined below to obtain a diverse, representative, and complete collection

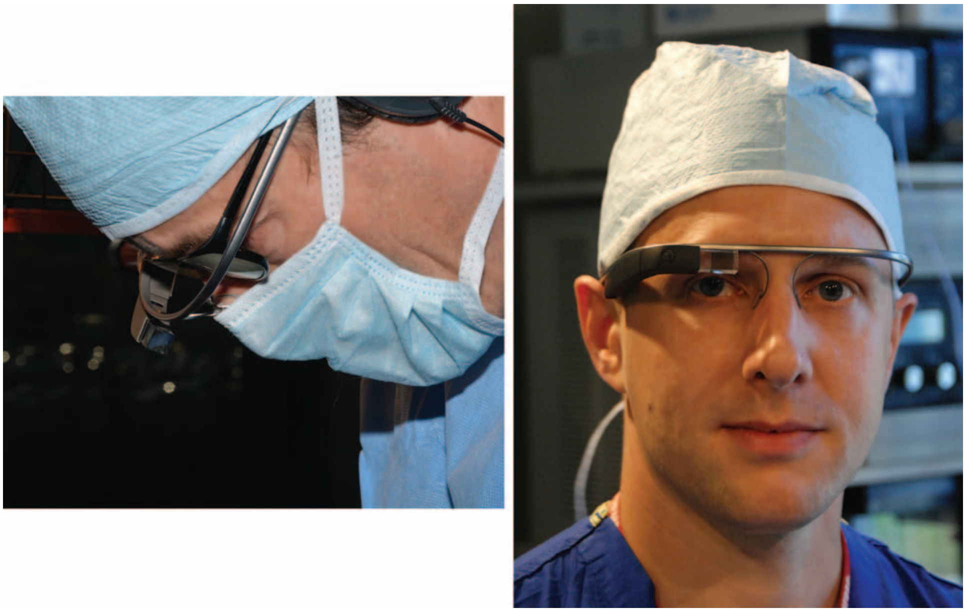

Fig. 1. Google Glass in the operating room. (*Left*) Lorne K. Rosenfield, M.D., wearing Google Glass (lateral view). (*Right*) Christopher R. Davis, M.R.C.S., wearing Google Glass (portrait view).

of Google Glass evidence within the medical and scientific literature.

Search Strategy

PubMed National Center for Biotechnology Information, Ovid MEDLINE (including in-process and other nonindexed citations), and the Cochrane Central Register of Controlled Trials were independently searched for Google Glass publications. Key words "Google" and "Glass" were used to identify potential publications, before manually screening articles for relevance to medicine and science. Further inclusion criteria included limiting searches to human studies published in English up to and including May of 2014. Abstracts and conference reports were included for completion, with reduced emphasis placed on their findings because of potentially incomplete information and contributions to subsequent publications. Duplicate records were excluded, with titles and abstracts of remaining citations screened for eligibility using the predetermined selection criteria.

Full publications were obtained, with each article individually searched for the presence of the word "Glass." Additional publications were selected by manually screening reference lists and recommendations. Publications were categorized as formal articles (defined as introducing novel content within a traditionally structured manuscript), editorial/commentary articles (defined as first-person articles not in traditional manuscript format), conference proceedings (defined as published abstracts from a conference) or news reports (defined as published news articles in a formal journal), or online articles (defined as a journalistic online articles).

Clinical Report of the First Google Glass Procedure in Plastic Surgery

The first Google Glass–recorded plastic surgery procedure was performed on October 29, 2013, by the senior author, Lorne K. Rosenfield, M.D., as reported by the American Society for Aesthetic Plastic Surgery.[6] Patient consent was granted for recording and publication of the lower lid blepharoplasty performed wearing Glass, with further details and video link in the results section below. This article is the first full description of the precise operative details of the case. Results from subsequent plastic surgical procedures (face lift and rhinoplasty) recorded by Glass are also outlined.

RESULTS

Systematic Review

Eighty-two publications were identified from this systematic review, of which 21 provided evidence of Google Glass application within medicine, science, and plastic surgery (Table 1).[1,3,6,7–24] Publication selection is outlined in the modified Preferred Reporting Items for Systematic Reviews and Meta-Analyses chart, incorporating data from all search methods (Fig. 2). Publications were identified from PubMed National Center for Biotechnology Information, Ovid MEDLINE or reference citations or hand searching, with no Google Glass data present on the Cochrane Central Register of Controlled Trials database.

Publication categories included for analyses were formal articles ($n = 3$), editorial/commentary articles ($n = 7$), conference proceedings ($n = 1$), news reports ($n = 3$), and online articles ($n = 7$). Of the formal articles, Google Glass has been successfully trialed in pediatric surgery, laboratory diagnostics, and forensic medicine.[7–9] The majority of evidence consisted of Google Glass user reports or journalistic online articles, with informal reports from multiple surgical specialties. The first reported surgical procedure wearing Glass was on June 20, 2013, by Rafael Grossmann, M.D., at Eastern Maine Medical Center (Bangor, Me.). Percutaneous endoscopic gastrostomy insertion was recorded with Glass and streamed by means of Google Glass Hang-Out on an iPad (Apple, Inc., Cupertino, Calif.). An internationally streamed operation occurred the next day (June 21, 2013), performed by Dr. Pedro Guillén, Head of Traumatology at Clínica CEMTRO in Madrid, Spain.[18] Chondrocyte implantation was performed in Madrid, Spain, with remote assistance from Homero Rivas, M.D., at Stanford University, and streamed internationally. A chronology of the first surgical procedures formally reported using Google Glass is presented (Table 2).[6,18,20–22,24,25]

Clinical application of Glass was thoroughly tested by a pediatric surgeon wearing Glass continuously during 4 weeks of clinical activities.[7] The technology recorded images from the ward and operating room, made phone calls to colleagues, performed Internet searches of pediatric pathology, practiced telementoring, and accessed billing codes.[7] User, colleagues, and patients positively embraced Glass and supported its integration in the clinical environment. Ergonomically, the user's field of vision was unimpeded by the prism, and voice activation permitted hands-free use during surgery. However, tilting of the surgeon's head

Table 1. Summary of Google Glass Evidence Base

Reference	Field	Publication Category	Identification Source			Publication Summary
			PubMed	MEDLINE	Other	
Muensterer et al., 2014[7]	Pediatric surgery	Paper	Yes	Yes		Continuous Glass use in a pediatric clinical setting for 4 wk; positive data from clinicians and patients, but low battery life and data protection issues highlighted
Feng et al., 2014[8]	Laboratory diagnostics	Paper	Yes	Yes		Glass application to run, process and store rapid diagnostic tests and read Quick Response codes
Albrecht et al., 2014[9]	Forensic medicine	Paper	Yes	Yes		Glass photographs compared with traditional digital single-lens reflex images in postmortem analyses
Parviz, 2014[10]	Laboratory diagnostics	Editorial	Yes	Yes		Editorial accompanying article by Feng et al.[8]
Technology and Trends, 2014[11]	Surgery	Commentary		Yes		Summary of surgical advances using Glass (unreferenced)
Glauser, 2013[12]	Medicine	Commentary	Yes	Yes	Cited[1]	Summary of medical application of Glass and early users
Scheck, 2013[13]	Emergency medicine	Commentary		Yes		Emergency medicine department introduction to Glass testing
Fox and Felkey, 2013[14]	Pharmacy	Commentary	Yes	Yes		Hospital pharmacy viewpoint on potential Glass incorporation to scan, verify and document medication dispensing
Parslow, 2014[15]	Biochemistry	Commentary	Yes	Yes		Google X synopsis and educational potential of Glass
Rosenfield, 2013[6]	Plastic surgery	Commentary			Hand	First plastic surgical procedure (blepharoplasty) recorded by means of Glass
Drumm et al., 2013[16]	Obstetrics/gynecology	Abstract		Yes		Recorded training of obstetric and gynecologic medical simulation using Google Glass
In The News, 2014[17]	Optometry	News report		Yes		Optician use of Google Glass
In The News, 2014[3]	Optometry	News report		Yes		Prescription lenses for Google Glass
Kurswel, 2013[18]	Orthopedic surgery	Online report			Cited[17]	First orthopedic surgery procedure (chondrocyte implantation) performed and recorded in Madrid, Spain, and streamed to Stanford, Calif.
Dunn, 2013[19]	Education	Online report		Yes	Cited[17]	Practical advice on incorporating Glass as a teaching tool, integrating with Twitter and awareness of privacy issues
de Pison, 2013[20]	Dental/maxillofacial surgery	Online report			Hand	Dental implant surgery performed and streamed by means of Glass
Leong, 2013[21]	Cardiothoracic surgery	Online report			Cited[1]	Thoracic surgery performed in ten cases by Dr. Pierre Theodore; investigative imaging viewed by means of Glass intraoperatively; all patients embraced Glass technology
Ohio Newsroom, 2013[22]	Orthopedic surgery	Online report			Hand	Cruciate ligament surgery live-streamed by means of Glass to colleagues and students
Oliver, 2013[23]	Orthopedic surgery	Online report			Cited[1]	Glass with Virtual Interactive Presence in Augmented Reality telemedicine surgery
Collman, 2013[24]	General surgery	Online report			Cited[15]	Percutaneous endoscopic gastrostomy insertion as first Glass-recorded procedure

caused inadvertent activation of Glass in the operating room. Battery life when used sporadically on a typical day in the hospital ranged from 8.5 to 10 hours but, for continuous recording in the operating room, was reduced to approximately 2.5 hours. Consent was conducted appropriately within this study, although skepticism was raised that the technology could be used unprofessionally for recording without consent.

Glass generates images and videos of adequate quality from ward rounds, clinics, and the operating room,[7] all of which would be usable within

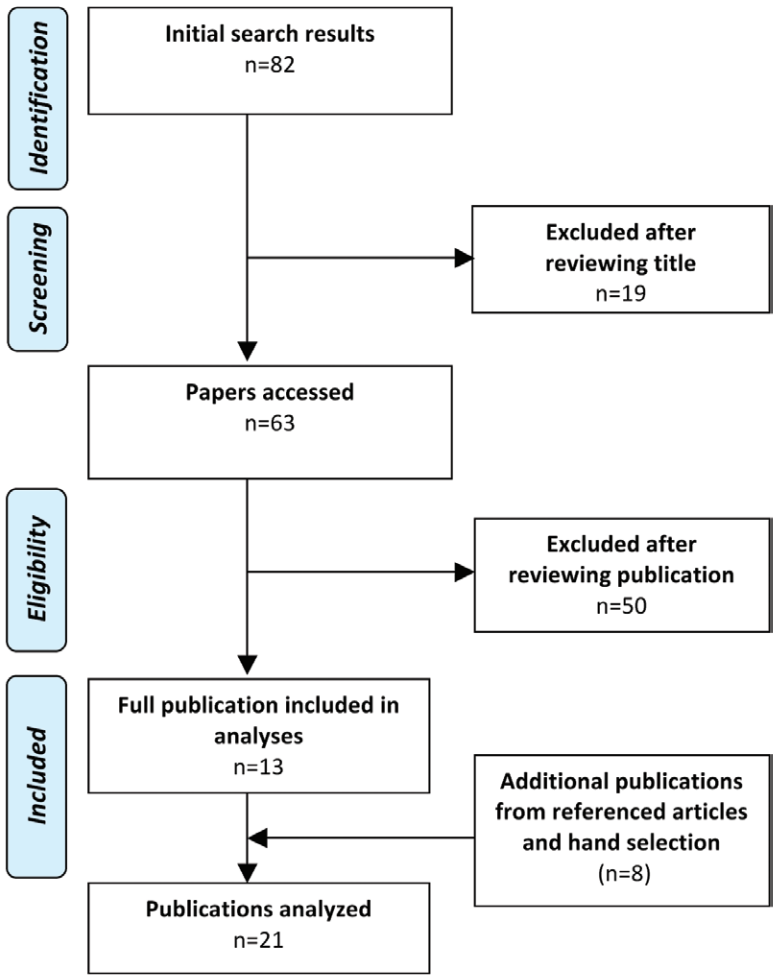

Fig. 2. Flow diagram of systematic review article selection, following modified Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines

Table 2. Chronology of Surgical Procedures Performed Using Google Glass by Location and Speciality

Date	Surgeon(s)	Location	Surgical Speciality	Details
June 20, 2013	R. Grossmann	Bangor, Me.	General surgery	Percutaneous endoscopic gastrostomy insertion[24]
June 21, 2013	P. Guillén	Madrid, Spain	Traumatology	Chondrocyte implantation[18]
August 21, 2013	C. Kaeding	Columbus, Ohio	Orthopedic surgery	Anterior cruciate ligament surgery[22]
August of 2013	P. Theodore	San Francisco, Calif.	Cardiothoracic surgery	Thoracic drainage[21,25]
October 26, 2013	P. Martínez, J. Gómez, and A. Gómez	Murcia, Spain	Dental/maxillofacial surgery	Dental implant surgery[20]
October 29, 2013	L. Rosenfield	Burlingame, Calif., Stanford and University of California, San Francisco	Plastic surgery	Blepharoplasty[6]

plastic surgery. Image quality is unfortunately inferior to a digital single-lens reflex camera for capturing anatomical images.[9] Performance deteriorated in poor lighting and absence of a zoom lens.[7] Audio quality may be compromised in busy hospital settings.[7] However, the senior author's (L.K.R.) practice of donning noise-cancelling headphones during plastic surgical procedures to augment the sound transmitted by means of Glass and applying a light-emitting headset overcome these difficulties effectively. Glass has also been used in the laboratory setting, with accompanying software developed to run, process, and store rapid diagnostic tests and read Quick Response

Codes at 99.6 percent accuracy.[8] Patient results can be uploaded onto a secure central server as part of the electronic medical records. Drawbacks highlighted included an inability of the camera to focus on close objects, akin to the macro setting of cameras, and average battery life during full recording of just 1 hour.

FIRST PLASTIC SURGICAL PROCEDURE

A bilateral blepharoplasty was performed on October 29, 2013, by the senior author (L.K.R.) wearing Google Glass to record and broadcast the operation (Fig. 3, *left*). A 71-year-old female patient consented for combined face lift with upper and lower blepharoplasty. After completing the face lift in the traditional manner, Glass was worn for the blepharoplasty component of the procedure. An intraoperative image of the first case is provided (Fig. 3, *right*), with video footage of the blepharoplasty case. (**See Video, Supplemental Digital Content 1**, which shows video footage of the first blepharoplasty case performed with Google Glass, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, available at www.operationglass.com and ***http://links.lww.com/PRS/B239***.)

Challenges from this case relate to surgical and technical factors from wearing the Glass while operating. Surgically, Glass did not adversely affect the visual field, and prescription glasses were comfortably worn behind the Google device at the surgeon's preference. (Optional integrated prescription lenses within the Glass frame have since been offered.) However, because Glass only allows for horizontal and not vertical adjustment of the camera, the surgeon had to maintain some neck hyperflexion to align the fixed camera of the Glass to focus on the operative field. Technically, to ensure power and allow for the surgeon's mobility, an extended Universal Serial Bus (USB) powered pocket battery was maintained attached. A portion of a standard sterile plastic drape (Steri-Drape) was used to cover the right temple arm of Glass to allow touch access of command gestures. The operation was streamed live, using Google Hangouts as the platform, to the two major university programs in the area (Stanford and the University of California, San Francisco). Noise-cancelling headphones (Bose; Bose Corp., Framingham, Mass.) were donned to augment sound and facilitate communication.

SUBSEQUENT PLASTIC SURGICAL PROCEDURES

The senior author has performed additional Google Glass–recorded operations. When recording a face lift, although poorer quality documentation was feared secondary to potentially

Fig. 3. First plastic surgery procedures performed with Google Glass. (*Left*) Lorne K. Rosenfield, M.D., in the operating room wearing Google Glass, noise-reducing headphones, and Steri-Drape to allow intraoperative touch contact with Google Glass temple arm during the first case on October 29, 2013. (*Right*) Intraoperative image of the first Google Glass plastic surgery patient.

Video. Supplemental Digital Content 1 shows video footage of the first blepharoplasty case performed with Google Glass, available in the "Related Videos" section of the full-text article on PRSJournal.com or, for Ovid users, available at www.operation-glass.com and ***http://links.lww.com/PRS/B239***.

distracting head movement, this concern did not come to pass. Our impression is that as surgeons we maintain a relatively stable head position when focused on a particular surgical step and, with practice, become more aware of this same mandate to "be still."

Closed rhinoplasty has also been performed using Glass by the senior author. This procedure is perfectly suited for broadcasting by means of Glass, given the restricted observer view. Surgical field illumination and resultant video quality was augmented by fashioning a headset with a powerful video light-emitting diode (LED) lamp (Fig. 4). This serves a dual function of improving image quality for the remote observer, but also adding dispersive light to the operative field for enhanced clarity for the surgeon. The absence of a vertical axis of the Glass camera—previously thought to be a negative design feature for the operating surgeon—in this instance becomes a positive feature, as the angle of the light-emitting diode headset *and* Google Glass are matched. The Glass, light-emitting diode, and surgeon's eyes are all synchronously focused on the same high-quality illuminated surgical field, creating an enhanced view for the surgeon and audience.

Fig. 4. Light-emitting diode headset used to augment Google Glass recording quality during procedures with limited lighting, such as rhinoplasty. The power cord leads to a battery in the rear pocket.

DISCUSSION

High-quality evidence for Google Glass application in medicine and science, and indeed plastic surgery, is limited, with just 19 articles and three formal research articles identified from this systematic review.[7–9] Despite technological infancy and few high-level research articles, the available data demonstrate positive features from implementing Google Glass in terms of surgical training, medical documentation, and patient safety that are applicable to contemporary plastic surgery.

Enhanced Surgical Training

Glass may revolutionize modern plastic surgical training through a number of applications. If an expert surgeon wears Glass to operate, training can be augmented by streamed expert master classes, where junior surgeons view the procedure from the expert operator's point of view. This may be particularly useful during the raising of a free flap, and dissecting the chosen plane or pocket for breast augmentation. In addition to seeing the operation in high quality "through the eyes" of an expert, obstacles for trainees in the operating room such as poor visibility, bad lighting, and uncomfortable positioning are overcome. Procedures performed by leading experts could be broadcast internationally and viewed by any junior surgeon at a subsequent time, offering the best seats in the house to a global audience of surgical trainees. This demonstrates a humanitarian potential too by contributing to global education by means of massive open online courses.[26] Expert recordings of operations could also contribute to certification when compiling case studies for the American Society of Plastic Surgeons board certification or even recertification for attending plastic surgeons.

Junior surgeons also benefit from wearing Glass. Residents operating independently can have focused discussions about cases mid-procedure with their seniors, as both may simultaneously visualize the procedure at different locations, thus providing real-time answers to intraoperative uncertainties and improving patient safety. For example, a more complex fracture than envisaged from imaging can be discussed with a senior surgeon with regard to the optimal fixation method. Virtual Interactive Presence in Augmented Reality telemedicine surgery can take this further by allowing the "hands" of a remote expert colleague to be superimposed within the surgical field to offer intraoperative guidance.[23] Augmented reality permits computer-generated anatomical images of deeper structures to be superimposed onto the skin. This would assist in flap planning, for example, where the pedicle or perforator could be "visualized" before incision. Furthermore, junior surgeons can view key components of procedures, such as the pinch blepharoplasty,[27,28] before, during, or after performing or assisting in similar procedures, which could be a game changer in terms of plastic surgical training.

Improved Medical Documentation

Glass enhances the viewing of medical documentation through rapid access to documentation while on the move or in remote areas. The consent process is similar to that for existing modalities, and images and videos are not recorded without verbal or tactile instruction. Furthermore, the simplicity of taking clinical photographs or audiovisual recordings allows contemporaneous recordings to supplement digital patient records. Files can be easily viewed at a later date and disseminated if necessary, which is particularly useful for more litigious specialities such as plastic and aesthetic surgery, where contemporaneous documentation has been shown to reduce litigation.[29] Intraoperative images provide evidence for the patient, surgical colleagues, or expert witness to visualize the extent of disease or trauma, and allow laboratory diagnosticians to have a macroscopic in vivo image of the sample that has been sent for analysis to aid their interpretation.

Ward rounds can be modernized and increasingly devoted to direct patient contact, as patient notes, laboratory results, and imaging can be accessed by means of Glass while walking to the patient. All members of the team can access the notes simultaneously and offer individual opinions and expertise on the clinical situation.

Emergency plastic surgery for burns or trauma typically follows acute presentations to the emergency department. Despite current efforts to relay information from the field to the receiving tertiary referral centers, assessments made in the field by non–plastic surgeons may be inaccurate. Examples include incorrectly assessing the surface area or depth of a burn,[30,31] miscalculating fluid resuscitation,[32] or nonadherence with standards of managing open lower limb fractures.[33] Paramedics and first responders, armed with Glass, could relay important visual data to the receiving expert, who may provide additional advice for immediate management in the field and more fully understand the extent of the incoming patient's injuries before safe and timely hospital transfer.

Patient Safety Benefits

Surgical safety checklists, such as those previously published,[47,48] can be incorporated within Glass. This may be a static image of the checklist displayed on the prism, or as a dynamic prompt for contemporaneous completion. In addition to Glass permitting "on-table" remote guidance from senior surgeons able to view the operative field of the junior surgeon, patient safety can be improved through numerous avenues with Glass. Many subjective decisions exist in plastic surgery that are reliant on visual assessment. For example, postoperative flap congestion can be viewed by a doctor wearing Glass on the ward and discussed remotely with the operating surgeon before discussion with the patient and taking consent to return to the operating room. A patient's preoperative imaging is available to the surgeon in the operating room using Glass, where a relevant preoperative scan can assist surgical planning and patient safety, particularly during minimally invasive procedures.[34]

Hospital-acquired infection rates may be improved by Glass, as clinicians can verbally activate the device to view notes or access investigations, thus reducing potential sources of bacteria from contact with ward computers, telephones, or paper notes. Methicillin-resistant *Staphylococcus aureus* transmission may be reduced, given frequent bacterial colonization of pens, patient notes, and environmental surfaces in the hospital setting,[35–37] despite improvements in infection control practice.[38]

Limitations of Google Glass and Cost Analysis

Google Glass, like many technologies, can only realize its potential with sufficiently advanced, user-friendly, and continuously evolving software. The device must be easy to control by an external user who fully understands the gadget. Fear of the unknown may falsely deter technophobes from trialling the device, whereas unquestioning support may blind enthusiasts to potential flaws. This review has used evidence from multiple specialities, fields, and locations, resulting in globally

Fig. 5. Surgical recording using traditional methods as a comparison to Google Glass.

positive support for Google Glass in the medical and scientific setting. Battery life, ergonomics, photographic/video quality, and cellular/streaming capabilities could all be improved.

A number of similarities exist between Google Glass and surgical robotics in terms of clinical introduction. The robotics literature cites numerous advances, and challenges, using the da Vinci surgical robot (Intuitive Surgical, Inc., Sunnyvale, Calif.).[39–44] Similarities include user learning curve, technological challenges from incorporating a new device, and providing robust evidence and outcomes to support the technology.[45,46] Furthermore, financial and nonfinancial costs exist with all new technologies. In an attempt to quantify recording costs, we performed a cost analysis comparing Google Glass with a professional medical videography team to record a plastic surgical procedure (Fig. 5). Financial costs from Google Glass include the fixed one-time device cost of $1500 with optional portable power pack ($20) for a total cost of $1520. In comparison, the recurring cost of using two videographers ($1500) with postproduction costs ($750) brings the total expense to $2250 for each operation. Thus, Google Glass is financially cost-effective. Furthermore, nonfinancial cost savings from the simplicity of Glass are vast compared with using a recording team. The presence of non–medically qualified staff in the operating room causes crowding, disrupts the atmosphere, and interrupts the flow and potential sterility of a procedure. Time is required to select photographic staff and coordinate the logistics for attending a desired case, compared to Google Glass' perpetual availability and complementary use without prior notice. Traditional surgical recordings may require an operative pause to illustrate a key step. This negatively impacts on a streamlined, sequential, and safe procedure and adds a further complex variable to an otherwise step-by-step routine.[47]

Live streaming is an area of particular weakness compared with a formal recording and playback. In a traditional recording, Glass captures footage and processes it into a file for full integrity sharing. However, in live streaming, the Internet is required as a "middleman," compromising image quality. As Glass records surgery, it instantaneously streams footage to the receiver, reliant on suboptimal wireless technology. Glass compresses the footage to reach the receiver in time, causing a decrease in resolution. Live streaming also runs the risk of network failures at either side of the connection, causing freezing or frame rate drops in the stream, and a loss of seamless image quality.

However, streaming has great potential for future iterations of Glass hardware, coupled with software advances. Despite this limitation, in its current form, Glass has immediate value for recording high quality video that can be uploaded, saved, and disseminated.

Further negative concerns exist regarding inappropriate recording using Glass, patient confidentiality from stored files, technological failure, and integration with existing formats.[7,8] Formal legislation to consider includes the Health Insurance Portability and Accountability Act and protected health information. Logistical, ethical, and hospital legislative issues need to be overcome to introduce Google Glass to clinical practice, which has been achieved in university-affiliated hospitals after receiving institutional review board clearance, and to private practice.[34] Given the expanding software options for Google Glass explored in Part II of this series, the future of Glass is promising and has the potential to make a positively disruptive impact for the contemporary plastic surgeon.

CONCLUSIONS

Google Glass has powerful potential to augment surgical training, medical documentation, and patient safety for contemporary plastic surgery, and is an exciting translational technology for clinical practice. There is a paucity of peer-reviewed research articles on Google Glass, with only three formal research articles identified from this systematic review of the current evidence base. To match the explosion of interest and technological advances, well-conducted high-quality research articles to quantify the benefits, and potential drawbacks, of adopting Google Glass within plastic surgery are required. This article reports the first plastic surgical procedures performed and recorded using Google Glass; we hope to stimulate scientific and surgical interest in this fascinating technological addition to our innovative and inquisitive speciality.

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PATIENT CONSENT

The patient provided written consent for the use of her image.

REFERENCES

1. Chandawarkar RY. Discovery or innovation? *Plast Reconstr Surg.* 2007;119:1104–1105.
2. Mathes SJ. Innovation. *Plast Reconstr Surg.* 2007;120:2110–2111.
3. In The News/New Products: Google partners with vision insurance company. *Optom Vis Sci.* 2014;91:e100.
4. Google, Inc. Google Glass: Designed for those who move. Available at: http://www.google.com/glass/start/what-it-does/. Accessed May 26, 2014.
5. Liberati A, Altman DG, Tetzlaff J, et al. The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate healthcare interventions: Explanation and elaboration. *BMJ* 2009;339:b2700.
6. Rosenfield LK. Google Glass and the surgeon. *Aesthetic Soc News* 2014;18:32–34.
7. Muensterer OJ, Lacher M, Zoeller C, Bronstein M, Kübler J. Google Glass in pediatric surgery: An exploratory study. *Int J Surg.* 2014;12:281–289.
8. Feng S, Caire R, Cortazar B, Turan M, Wong A, Ozcan A. Immunochromatographic diagnostic test analysis using Google Glass. *ACS Nano.* 2014;8:3069–3079.
9. Albrecht UV, von Jan U, Kuebler J, et al. Google Glass for documentation of medical findings: Evaluation in forensic medicine. *J Med Internet Res.* 2014;16:e53.
10. Parviz BA. Of molecules, medicine, and Google Glass. *ACS Nano.* 2014;8:1956–1957.
11. Could Google Glass become surgeons' newest technology of choice? *J Clin Eng.* 2014;39:57–58.
12. Glauser W. Doctors among early adopters of Google Glass. *CMAJ* 2013;185:1385.
13. Scheck A. Seeing the (Google) glass as half full. *Emerg Med News* 2014;36:20–21.
14. Fox BI, Felkey BG. Potential uses of Google glass in the pharmacy. *Hosp Pharm.* 2013;48:783–784.
15. Parslow GR. Commentary: Google glass: A head-up display to facilitate teaching and learning. *Biochem Mol Biol Educ.* 2014;42:91–92.
16. Drumm J, Eason M, Olsen M. Introduction of Google Glass to the medical simulation lab. *Soc Simulation Healthcare* 2013;8:431.
17. In The News/New Products: Google Glass for optometrists and ophthalmologists? *Optom Vis Sci.* 2014;91:e23–e27.
18. Kurzweil R. Spanish doctor performs first surgery transmitted live via Google Glass. Available at: http://www.kurzweilai.net/spanish-doctor-performs-first-surgery-transmitted-live-via-google-glass. Accessed 21 May 2014.
19. Dunn J. The teacher's guide to Google Glass. Available at: http://www.edudemic.com/the-teachers-guide-to-google-glass/. Accessed May 22, 2014.
20. de Pison J. First maxillofacial surgery in the world broadcast with Google Glass. Available at: http://www.dental-tribune.com/articles/news/europe/15315_first_maxillofacial_surgery_in_the_world_broadcast_with_google_glass.html. Accessed May 21, 2014.
21. Leong KC. A surgeon's review of Google Glass in the operating room. Available at: http://www.fastcompany.com/3022534/internet-of-things/a-surgeons-review-of-google-glass-in-the-operating-room. Accessed May 25, 2013.
22. The Ohio State University Multimedia Newsroom. Point-of-view surgery shown via Google Glass. Available at: http://osuwmc.multimedianewsroom.tv/story.php?id=663&enter=. Accessed May 25, 2014.
23. Oliver M. UAB doctor performs surgery using Google Glass. Available at: http://blog.al.com/spotnews/2013/10/uab_surgeon_performs_surgery_u.html. Accessed May 25, 2014.
24. Collman A. First ever surgery conducted by doctor wearing Google glass. *Daily Mail Online.* Available at: http://www.dailymail.co.uk/news/article-2346442/First-surgery-conducted-doctor-wearing-Google-glass.html. Accessed July 17, 2014.
25. Brown KV. Using Google Glass in the OR. Available at: http://blog.sfgate.com/chronrx/2013/09/12/using-the-google-glass-in-the-or/. Accessed May 31, 2014.

26. Parslow GR. Commentary: Massive open online courses. *Biochem Mol Biol Educ.* 2013;41:278–279.
27. Rosenfield L. Pinch blepharoplasty: A safe technique with superior results. *Aesthet Surg J.* 2007;27:199–203.
28. Rosenfield LK. The pinch blepharoplasty revisited. *Plast Reconstr Surg.* 2005;115:1405–1412; discussion 1413–1414.
29. Avant Media. Surgeon shares the keys to his legal win. Available at: http://www.avant.org.au/News/20140414-surgeon-shares-legal-win/. Accessed June 12, 2014.
30. Gasperin M, Juricić D. The uncertainty in burn prediction as a result of variable skin parameters: An experimental evaluation of burn-protective outfits. *Burns* 2009;35:970–982.
31. Hammond JS, Ward CG. Transfers from emergency room to burn center: Errors in burn size estimate. *J Trauma* 1987;27:1161–1165.
32. Parvizi D, Kamolz LP, Giretzlehner M, et al. The potential impact of wrong TBSA estimations on fluid resuscitation in patients suffering from burns: Things to keep in mind. *Burns* 2014;40:241–245.
33. Stammers J, Williams D, Hunter J, Vesely M, Nielsen D. The impact of trauma centre designation on open tibial fracture management. *Ann R Coll Surg Engl.* 2013;95:184–187.
34. Kim L. Google Glass delivers new insight during surgery. Available at: http://www.ucsf.edu/news/2013/10/109526/surgeon-improves-safety-efficiency-operating-room-google-glass. Accessed May 31, 2014.
35. Boyce JM. Environmental contamination makes an important contribution to hospital infection. *J Hosp Infect.* 2007;65(Suppl 2):50–54.
36. Hamza N, Bazoua G, Al-Shajerie Y, Kubiak E, James P, Wong C. A prospective study of the case-notes of MRSA-positive patients: A vehicle of MRSA spread. *Ann R Coll Surg Engl.* 2007;89:665–667.
37. Tadiparthi S, Shokrollahi K, Juma A, Croall J. Using marker pens on patients: A potential source of cross infection with MRSA. *Ann R Coll Surg Engl.* 2007;89:661–664.
38. Davis CR. Infection-free surgery: How to improve hand-hygiene compliance and eradicate methicillin-resistant *Staphylococcus aureus* from surgical wards. *Ann R Coll Surg Engl.* 2010;92:316–319.
39. Bonawitz SC, Duvvuri U. Robot-assisted oropharyngeal reconstruction with free tissue transfer. *J Reconstr Microsurg.* 2012;28:485–490.
40. Boyd B, Umansky J, Samson M, Boyd D, Stahl K. Robotic harvest of internal mammary vessels in breast reconstruction. *J Reconstr Microsurg.* 2006;22:261–266.
41. Facca S, Hendriks S, Mantovani G, Selber JC, Liverneaux P. Robot-assisted surgery of the shoulder girdle and brachial plexus. *Semin Plast Surg.* 2014;28:39–44.
42. Karamanoukian RL, Finley DS, Evans GR, Karamanoukian HL. Feasibility of robotic-assisted microvascular anastomoses in plastic surgery. *J Reconstr Microsurg.* 2006;22:429–431.
43. Selber JC. Transoral robotic reconstruction of oropharyngeal defects: A case series. *Plast Reconstr Surg.* 2010;126:1978–1987.
44. Siemionow M, Ozer K, Siemionow W, Lister G. Robotic assistance in microsurgery. *J Reconstr Microsurg.* 2000;16:643–649.
45. Selber JC. Robotics in plastic surgery. *Semin Plast Surg.* 2014;28:3–4.
46. Selber JC, Alrasheed T. Robotic microsurgical training and evaluation. *Semin Plast Surg.* 2014;28:5–10.
47. Rosenfield LK, Chang DS. The error of omission: A simple checklist approach for improving operating room safety. *Plast Reconstr Surg.* 2009;123:399–402.
48. Haynes AB, Weiser TG, Berry WR, et al. A surgical safety checklist to reduce morbidity and mortality in a global population. *N Engl J Med.* 2009;360:491–499.