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Participatory Development of a 3D Telemedicine system during Covid: the future of remote consultations

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Short running head: 3D Telemedicine during Covid

Abstract

Background

The Covid pandemic brought the need for more realistic remote consultations into focus. 2D telemedicine solutions fail to replicate the fluency or authenticity of in-person consultations. This research reports on an international collaboration on the participatory development and first validated clinical use of a novel, real-time 360-degree 3D Telemedicine system worldwide. Development of the system - leveraging Microsoft's Holoportation™ communication technology – commenced at Canniesburn Plastic Surgery Unit, Glasgow in March 2020.

Methods

Research followed VR CORE guidelines on development of Digital Health trials, placing patients at the heart of the development process. This consisted of three separate studies - a clinician feedback study (23 clinicians, Nov-Dec 2020), a patient feedback study (26 patients, Jul-Oct 2021), and a cohort study focusing on safety and reliability (40 patients, Oct 2021 - Mar 2022). *á[2ăŜΣ YŜŜLJ I·yŘ /KI·yƎŜɛ* feedback prompts were used to engage patients in the development process and guide incremental improvements.

Results

Participatory testing demonstrated improved patient metrics with 3D in comparison to 2D Telemedicine, including validated measures of satisfaction ($p<0.0001$), realism or 'presence' (Single Item Presence scale, $p<0.0001$), and quality (Telehealth Usability Questionnaire,

p=0.0002). Safety and clinical concordance (95%) of 3D Telemedicine with a face-to-face consultation were equivalent or exceeded estimates for 2D Telemedicine.

Conclusions

One of the ultimate goals of telemedicine is for the quality of remote consultations to get closer to the experience of face-to-face consultations. These data provide the first evidence that Holoportation™ communication technology brings 3D telemedicine closer to this goal than a 2D equivalent.

Keywords: Telemedicine; 3 dimensional; remote consultation; Plastic Surgery; Covid 19; presence; realism

BACKGROUND

Real-time 3D Telemedicine has previously been proposed within a research setting only, with constraints on cost, complexity, bandwidth and technology [1, 2]. With the Covid Pandemic, use of remote consultation has increased exponentially and has brought the concept of a 3D consultation into focus [3]. Although there appears to be significant theoretical value in assessing surgical patients, as yet no validated clinical data exists on the benefits of such a system in comparison to standard 2D Telemedicine. Here we detail the participatory development of a real-time 3D Telemedicine system, in conjunction with an international group of healthcare and industrial stakeholders. We also discuss the first real-world use of a 3D Telemedicine system with Plastic Surgery patients.

Increasing access to care in Lower to Middle Income Countries

Initial discussions regarding the development of a 3D Telemedicine system, leveraging Microsoft's Holoportation communication technology, commenced in December 2019 - between Canniesburn Plastic Surgery Unit, Glasgow, UK; Korle Bu Teaching Hospital, Accra, Ghana; and Microsoft Corporation, Redmond, USA. This centered around the potential for increasing access to specialised reconstructive surgical care in Lower to Middle Income countries (LMIC). The research team visited the Ministry of Health, Ghana, in February 2020 to initiate an international collaboration on this project. Geospatial mapping set out the early vision, using census data and overland travel times to estimate increased access to reconstructive care [4]. With the global Covid pandemic enforcing the first UK lockdown in March 2020, the focus of the project rapidly pivoted to potential delivery of remote care during Covid.

VR CORE Guidelines on developing Digital Health technologies

The 3D Telemedicine system was co-developed with patients using international guidelines for digital or Virtual Reality (VR) clinical trials, as proposed by the Virtual Reality Clinical Outcomes Research Experts (VR CORE). These guidelines aim to improve methodological quality in digital health technology trials, dividing development into three phases (VR 1 to 3), akin to Clinical Trial Phases 1 to 3 [5]. Participatory development is one of the key elements of these guidelines, focusing on the principles of human-centered design. The importance of this in digital trials has been previously underestimated, as *άfI·Ŏ ļ 2ŦLJI·ŭΛŜyű involvement, poor requirement definitions, and non-adaptation to user feedback are some of the common factors that explain failures of digital interventions*" [5]. The present study placed patients at the heart of the development process and reports on the Participatory development (VR 1) and early Clinical Trial (VR 2) phases. The objectives of this research were to co-develop a patient-centered 3D Telemedicine system, compare validated outcome measures with a 2D system, assess alignment with an in-person consultation, and to ensure safety, reliability and clinical concordance.

METHODS AND RESULTS

Ethics

NHS Greater Glasgow and Clyde (GGC) R and I approvals GN20HS181/ GN20HS300. NHS GGC governance meetings monitored the project bi-annually. Participants consented in writing. Patient data controlled by NHS GGC. STROBE guidelines followed for reporting of cohort trials.

Approach and Preliminary Work

Research followed the VR CORE guidelines [5] and consisted of preliminary work including focus groups, stakeholder collaborations, equality assessments, and initial prototyping. Weekly collaboration meetings were held over a 2-year period in UK, Ghana and USA, commencing March 2020. To inform prototype development - a focus group was held with 23 clinicians from Canniesburn Plastic Surgery Unit, Glasgow, UK in June 2020 - exploring desired functions, identification of needs, potential benefits, risks, use during Covid, and implementation (Supplementary Table 1). An Equality Impact Assessment (EQIA) [6] focused on *ά*y2ű fŜI·Ő*λ*yƎ I·yêō2Řè ōŜK*λ*yŘ *λ*y′I· ŘλƎ*λ*ű*I*·f ǿ2ℕfŘɛ́ [7], and collected data on factors that may influence access or use of novel technology, such as deprivation and educational level. This was followed by three separate studies: a clinician feedback study – providing feedback to incrementally improve and shape the 3D Telemedicine sytem prior to patient testing; a patient feedback study – to compare 3D and 2D Telemedicine systems; and a cohort study focusing on safety, reliability and clinical concordance of 3D with face-to-face examination (Flowchart 1).

Flowchart 1

Prototyping and Initial Set up

Initial system set-up took place in September 2020, when a research team from Microsoft Corporation, Redmond, USA travelled to Glasgow, UK. The system – inspired by Microsoft's Holoportation™ research [8] - consisted of an array of 10 Azure Kinect cameras connected to a Fusion server that fuses each camera's depth output to create a 3D 360-degree model, and a Render server that covers the model in RGB video output. This was linked to a "viewer" room where the patient could be viewed in 360-degrees on a computer screen over the existing hospital network (Figures 1-5, Supplementary Videos 1-3). The "viewer" room was set up in both the test site hospital (West Glasgow Ambulatory Care Hospital, WGACH) and remotely at Canniesburn Plastic Surgery Unit. The WGACH viewer site was used in the present studies (full system features - Supplementary Table 1).

Figures 1-5

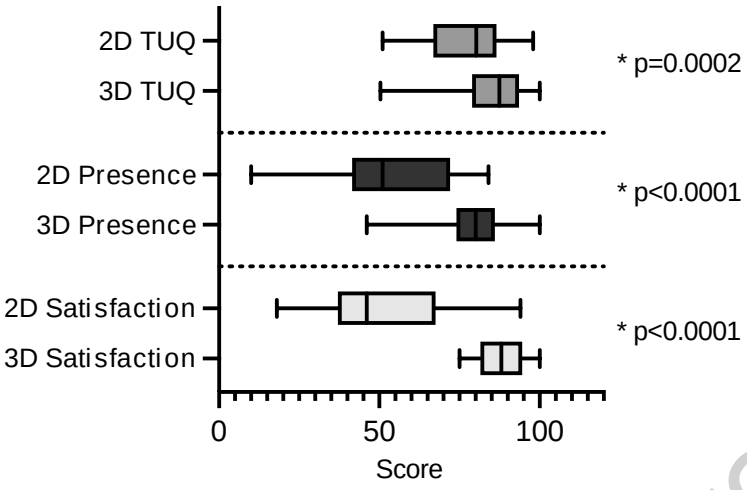
Supplementary Videos 1-3

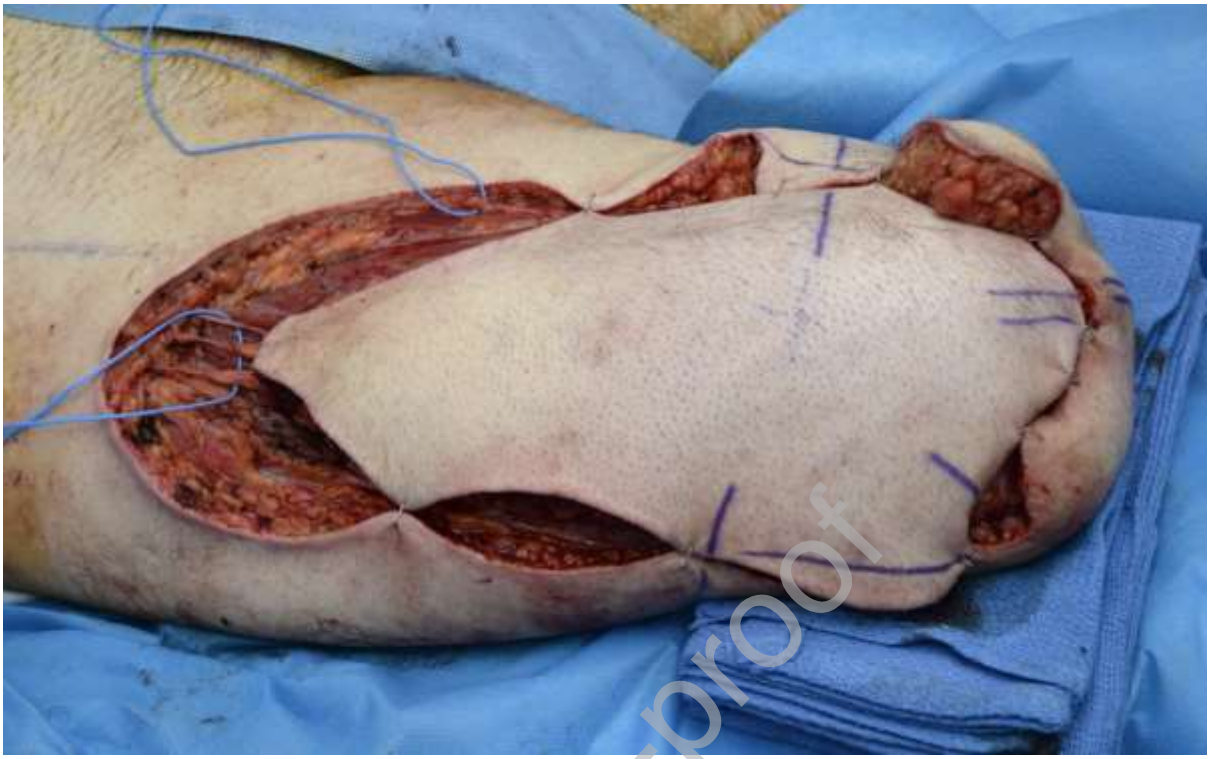
VR PHASE 1: PARTICIPATORY CO-DEVELOPMENT

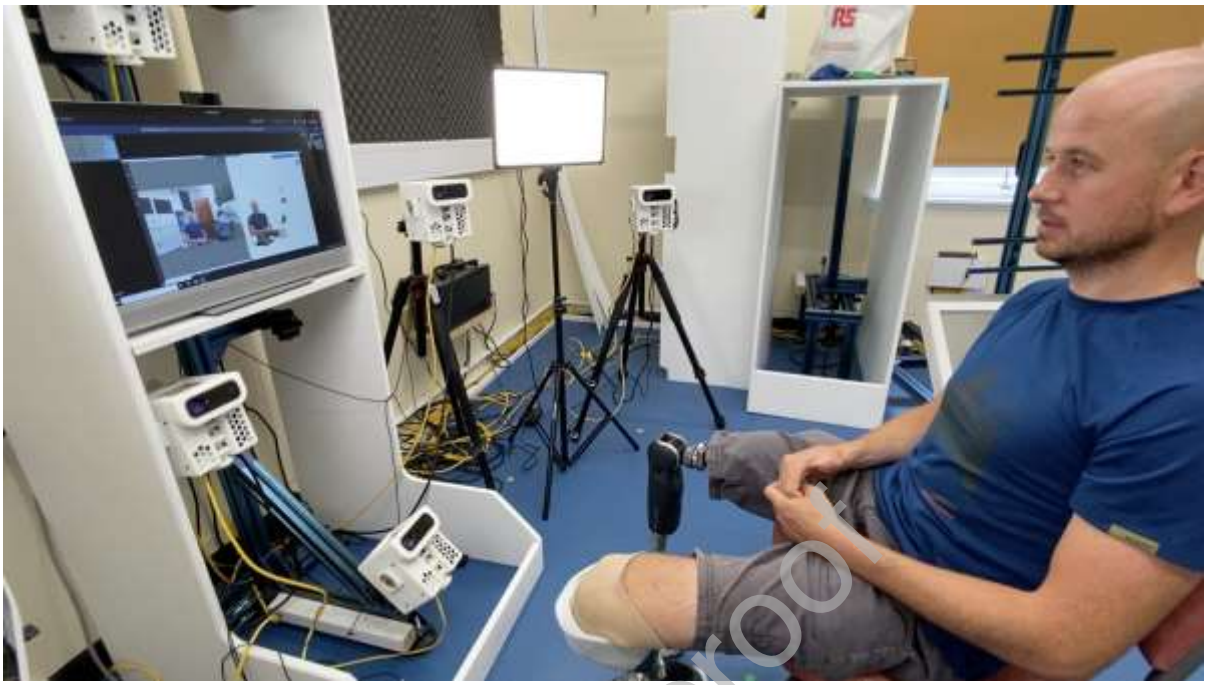
Patient and Clinician Participatory Development

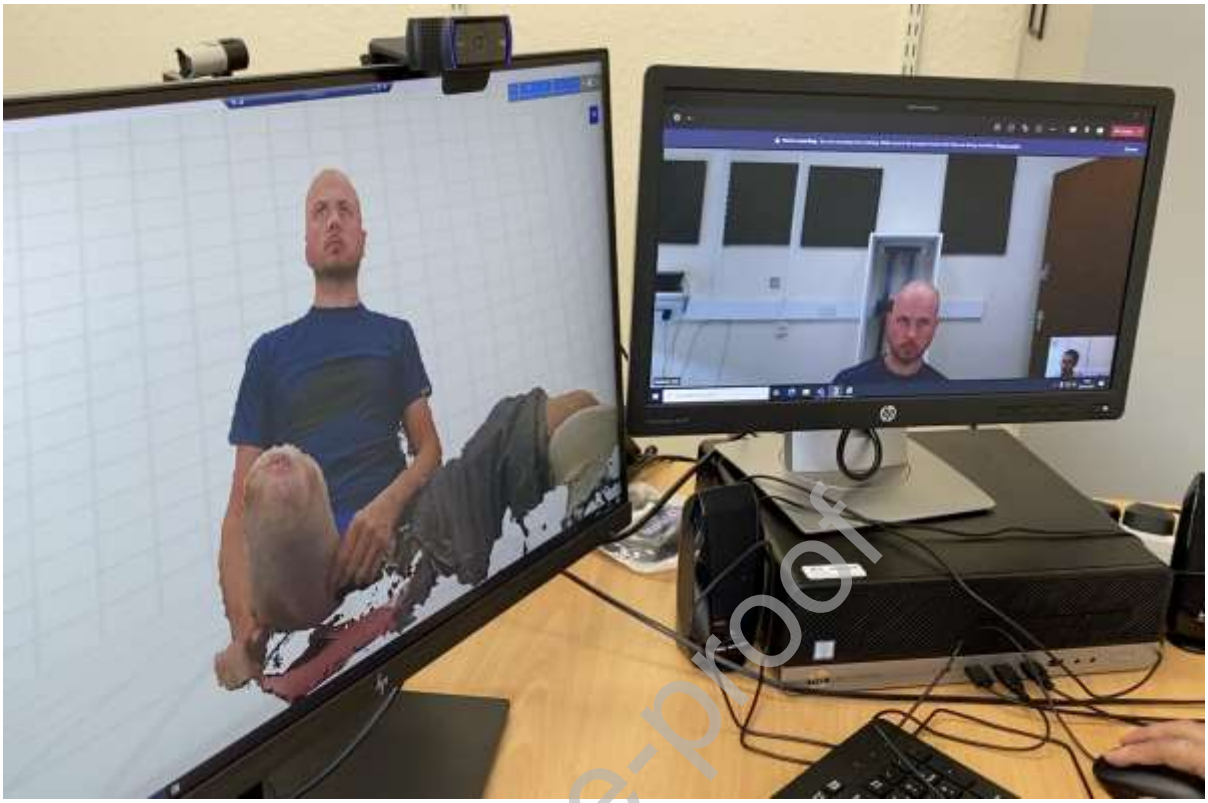
Patient and clinician feedback was used to shape the development of the 3D Telemedicine system, assess usability of the outcome instruments, and provide data for follow-on trials. Sample sizes were not required for the participatory development component of this study.

Boxplot 1: 3D versus 2D patient outcome measures. Satisfaction, Presence (Single Item Presence Scale) and Quality (TUQ) all significantly higher for the 3D system. All scores converted to 0-100 scale.









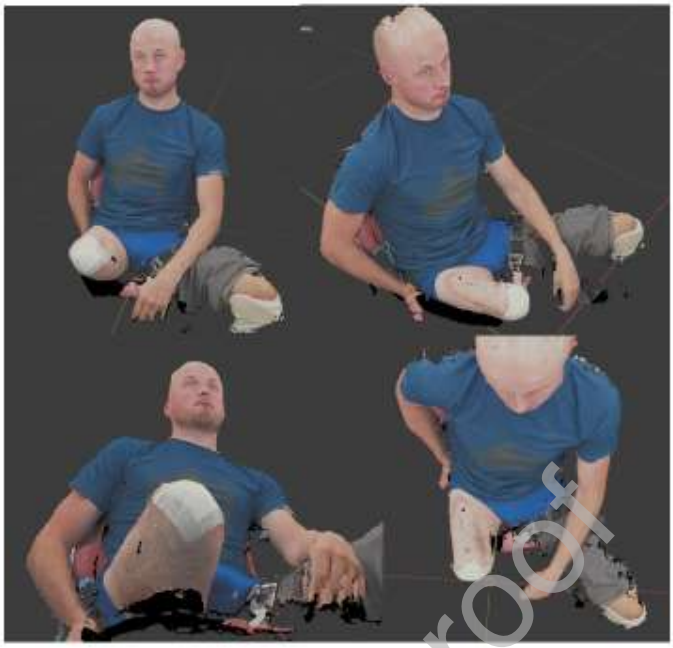


Figure Legends

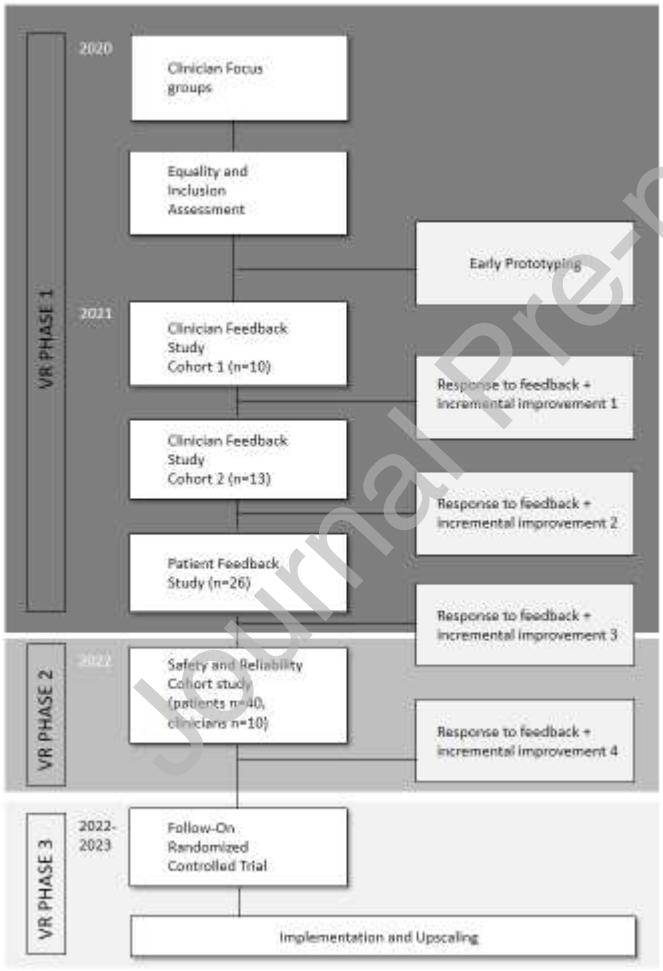
Figure 1: 3D Rig Set up. Multiple Kinect cameras surround the patient within the clinic room. In the centre is a chequerboard used to calibrate the system.

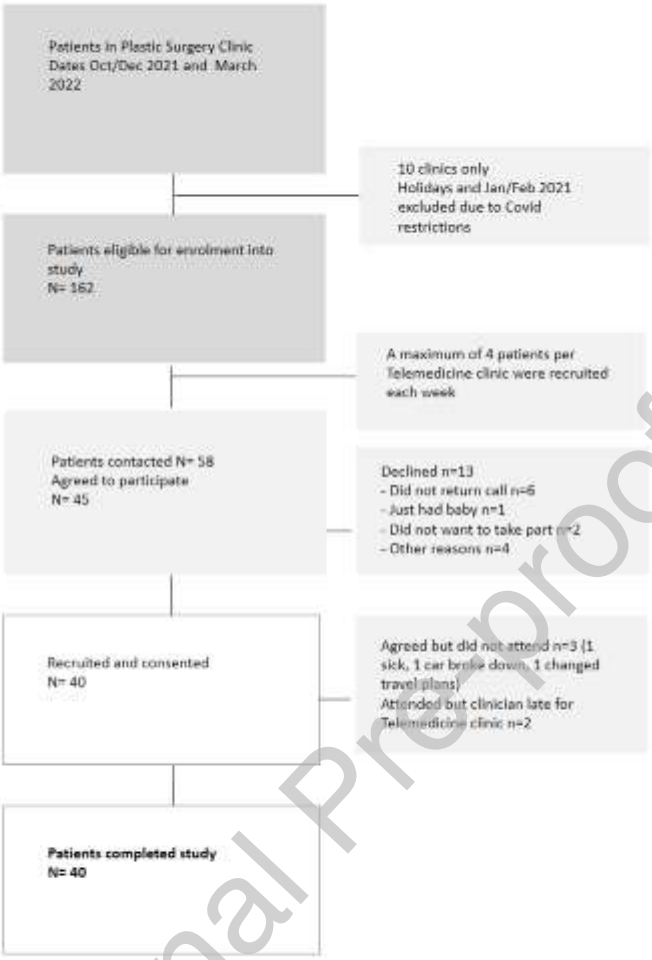
Figure 2: Sensate Anterolateral Thigh (ALT) Flap to Above knee amputation (AKA). This patient required resurfacing of an area of skin grafted post-traumatic residual limb, that provided a poor interface with the prosthetic limb. A sensate ALT flap was used to resurface the residual limb.

Figure 3: Patient in 3D rig. The same patient with resurfaced AKA sitting in the 3D Telemedicine system. The screen allows him to view the same images as the clinician.

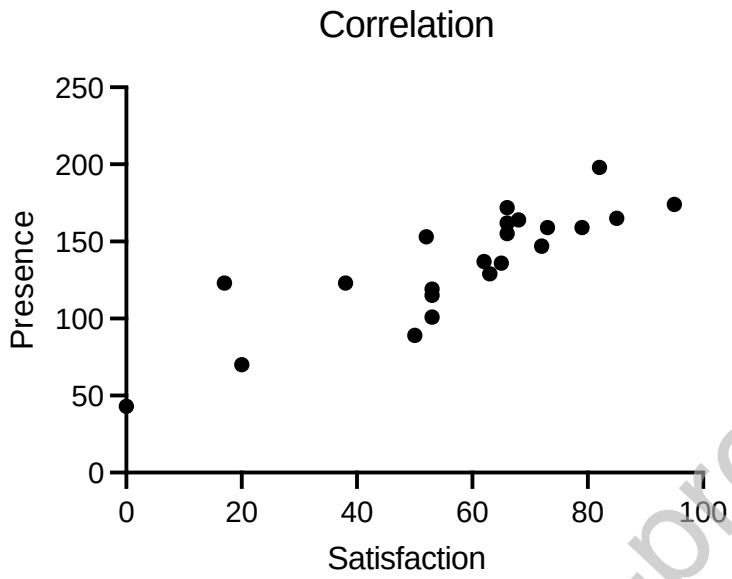
Figure 4: Clinician Viewer room. The clinician can see the patient in 3D on the left screen. On the right is a standard Telemedicine video call. Note the difference in field of view and ability to position patient to see the right AKA.

Figure 5: Multiple 3D views. These images demonstrate the 3D camera output in real time.





Graph 1: Correlation of Presence with Satisfaction. Clinician Satisfaction correlation with Presence Questionnaire Score



Graph 1: Improvements in outcomes during development process. Outcome measurements improved significantly during incremental feedback and development, for ratings of satisfaction, presence (PQ) and usability (SUS) over the development process. 2020 refers to scores from the Clinician Feedback Study Batch 1, 2021 refers to Clinician Feedback Study Batch 2, and 2022 to the Cohort study clinician scores. PQ is converted to a 100 point scale for this graph. 95% CI bars shown. Comparison of 2020 with 2022 scores with unpaired t-test: Satisfaction (p=0.026), PQ (p=0.021), SUS (p=0.017).