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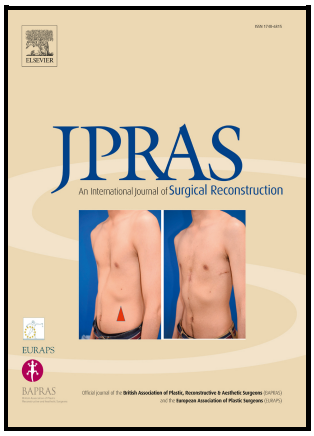

Ghana 3D Telemedicine International MDT: A Proof-of-concept studyShort running head: 3D Telemedicine International MDT

Steven Lo, Anna Rose, Spencer Fowers, Kwame Darko, Andrea Britto, Thiago Spina, Levi Ankrah, Arnold Godonu, Daniel Ntreh, Ruchi Lalwani, Catriona Graham, David Tittsworth, Aileen McIntyre, Chris O'Dowd, Stuart Watson, Roma Maguire, Amber Hoak, Opoku Ampomah, Ben Cutler

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Ghana 3D Telemedicine International MDT: A Proof-of-concept study

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Short running head: 3D Telemedicine International MDT

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Abstract

A real-time 3D Telemedicine system - leveraging Microsoft's Holoportation™ communication technology – enabled an international multidisciplinary team meeting (MDT) to consult with complex reconstructive patients prior, during, and after an overseas surgical collaboration.

Methods

A proof-of-concept international 3D MDT clinic took place in November 2022, between Canniesburn Plastic Surgery Unit, UK and the National Reconstructive Plastic Surgery and Burns Centre, Korle Bu Teaching Hospital, Ghana. The 3D system was utilised 1) pre-visit to assess patients and enable logistical planning, 2) on-site in Ghana to further allow patients to see themselves and proposed operations in 3D, and 3) post-visit to debrief team and patients.

Results

4 Ghana patients were followed through their patient journey (mandibular ameloblastoma, sarcoma thigh, maxillary tumour, sarcoma back). 13 participants (4 patients, 4 Ghana clinicians, 5 UK clinicians) completed feedback on the 3D MDT. Outcome measures were rated highly with satisfaction 84.31/100, perceived benefit 4.54/5, overall quality 127.3/ 147 (Telehealth Usability Questionnaire), and usability 83.2/100 (System Usability Scale). These data show close alignment with that previously published on high income countries.

Conclusions

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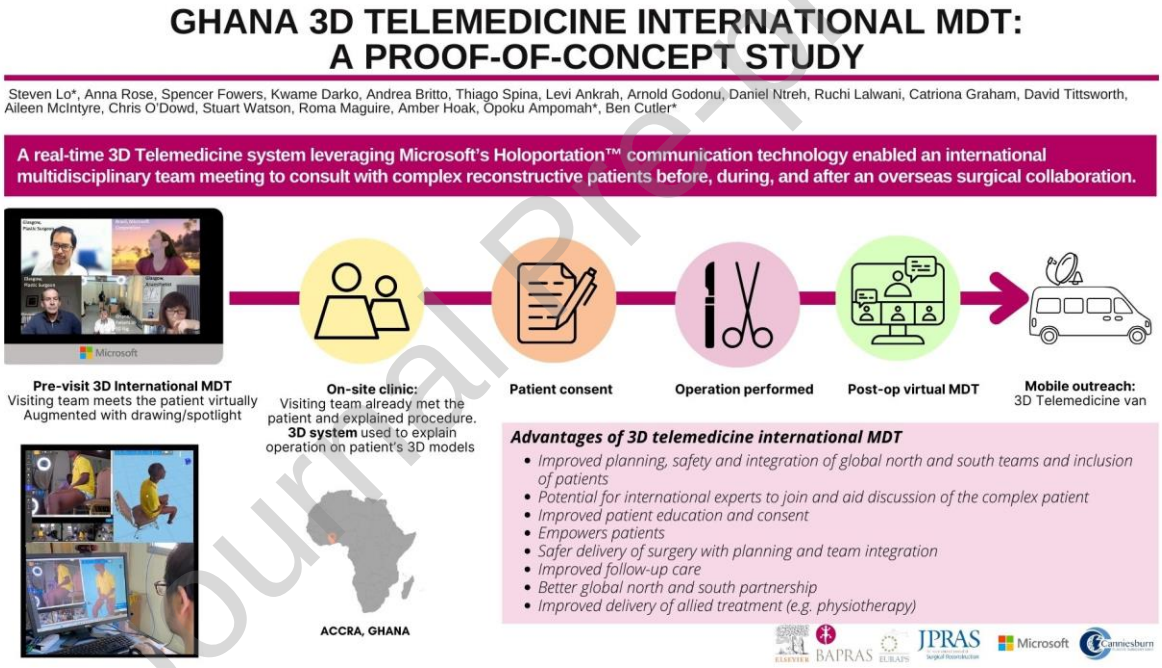
This novel technology has potential to enhance delivery of overseas surgical visits to low-to-middle income countries (LMIC), by improving planning, informed discussion with patients, expert consensus on complex cases, and fostering engagement with professionals who may be thousands of miles away. This is the first demonstration that real-time 3D Telemedicine can both work, and enhance care within an International MDT clinic, and may thus enable change in the approach to overseas surgical collaborations.

Graphical abstract



Keywords

Telemedicine; LMICs; Telehealth; Imaging, Three-Dimensional; Surgery, Plastic

BACKGROUND

One of the fundamental goals of Telemedicine is to increase the realism of the remote consultation, to more closely mimic the experience of an in-person consultation. With this in

mind, a real-time 3D Telemedicine system - leveraging Microsoft's Holoportation™ communication technology - has been recently co-developed with patients and validated for clinical use in Plastic and Reconstructive surgery, [1, 2]. Although in its infancy, this technology has potential to integrate into local healthcare systems and improve the delivery of overseas surgical visits to low-to-middle income countries (LMIC).

Co-development and Clinical Validation

An international collaboration commenced in December 2019, setting out to develop a 3D Telemedicine system for use in a low-resource setting, consisting of research teams from Canniesburn Plastic Surgery Unit, Glasgow, UK; Korle Bu Teaching Hospital, Accra, Ghana; and Microsoft Corporation, Redmond, USA. Using the principles of human-centered design proposed by the Virtual Reality Clinical Outcomes Research Experts (VR CORE) - the 3D Telemedicine system was co-developed with patients between 2020 and 2022 [3 1]. Testing focused on assessment of validated patient metrics in comparison to 2D Telemedicine, including measures of safety and reliability. This demonstrated increased patient satisfaction, closer alignment to a face-to-face consultation, and improved validated scores for quality in comparison to a 2D equivalent [1].

Increasing access to care in Lower to Middle Income Countries

The early vision for Microsoft's Holoportation™ communication technology was to increase access to specialised reconstructive surgical care in LMIC. Geospatial mapping - using census data and overland travel times – provided initial estimates for increasing timely access to specialised reconstructive care by 5 million people [2].

3D Telemedicine International MDT proof-of-concept

Although virtual reality has been used previously proposed in the context of cardiac MDTs, no previous clinical research has included international use of a real-time 3D Telemedicine system [4]. Here we discuss the first real-world use of a 3D Telemedicine system in the context of an international MDT. As a proof-of-concept study, this study focused on demonstrating technical feasibility using standard network connections and with a limited number of clinical patients in Ghana. Nonetheless this study also pointed to potential additional benefits that may be accrued - relating to improvements in planning, logistics, safety, patient education, and surgical team integration.

METHODS AND RESULTS

Ethics

Ethics approvals (KBTH-IRB 000218/2022) obtained from Ethics Board of Korle Bu Teaching Hospital, Ghana. Participants consented in writing. Patient data controlled by Korle Bu Teaching Hospital.

Approach and Preliminary Work

Research followed VR CORE guidelines and consisted of preliminary work including focus groups, stakeholder collaborations, equality assessments, and initial prototyping [1]. An initial on-site scoping visit to Korle Bu Teaching Hospital in February 2020 included stakeholder meetings with patients, clinical staff, academia, industry partners, and the Ministry of

Health, Ghana. The project evolved over a subsequent 2-year period, involving an international collaboration between the UK, Ghana and USA. Details of the development of the 3D Telemedicine involving patient and clinician feedback testing, safety and reliability, and a cohort trial are described in our previous publication [1]. Importantly, methodology was developed in close collaboration with the local team in Ghana to ensure that the system was contextually appropriate, with a Research Fellow from Ghana embedded within the Glasgow research team for 2 years.

Participants

A collaborative surgical visit to the National Reconstructive Plastic Surgery and Burns Centre, Korle Bu Teaching Hospital, Ghana, took place in November 2022, with 5 visiting surgeons and 6 anaesthetists from Canniesburn Plastic Surgery Unit, UK. 4 patients were included in the 3D Telemedicine International MDT proof-of-concept trial, including a maxillary SCC, ameloblastoma mandible, sarcoma back, and sarcoma thigh. All patients were operated on by both a consultant from Korle Bu Teaching Hospital and a consultant from Canniesburn Plastic Surgery Unit **(Supplememtary Table 1).**

Methods, Setting and Patient Journey

Initial system set-up took place in Ghana, in March 2022. The system – inspired by Microsoft's Holoportation™ research [5] - 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 **(Figure 1).** This was linked to a "viewer" room where the patient could be viewed in 360-degrees on a

computer screen. The "viewer" room was set up in both the test site hospital (Korle Bu Teaching Hospital, Ghana) and the remote international hospital (West Glasgow Ambulatory Care Hospital, WGACH, UK). The 3D Telemedicine system in Ghana could be controlled remotely from Glasgow using a commercial broadband connection at 5-10 Megabit (Mbps) **(Figure 2).**

The 3D Telemedicine International MDT consisted of three phases **(Flowchart 1)**:

1) Prior to international travel in Glasgow- to facilitate surgical planning and real-time patient assessment **(Figure 3).**

2) Pre-operatively on-site in Ghana - to aid in patient education and explain the proposed operation to patients **(Figures 4-7, Supplementary Figures 1-3).**

3) Post-operatively from Glasgow - for surgical follow-up and to effectively explain the surgery to patients **(Figure 8, Supplementary Figure 4).**

The whole process is illustrated with a patient with a mandibular ameloblastoma in **Supplementary Video 1.**

Surgical and anaesthetic staff from both UK (Global North) and Ghana (Global South) attended the international MDTs. All patients, Ghana, and UK clinicians were interviewed following their participation. Structured questionnaires were used [6] to guide feedback on the 3D System and international MDT process (data not shown). Outcome measures

included satisfaction measured on a visual analogue scale [7]. Usability was measured with the System Usability Scale (SUS), an industry standard scale that allows comparison across different technologies [8]. The Mental Effort Rating Scale measured the ease of use of the system [9]. Telehealth Usability Questionnaire (TUQ) measured overall quality of the system and consists of 21 items covering subdomains of usefulness, ease of use, effectiveness, reliability and satisfaction [10]. Statistical analysis performed with GraphPad Prism (version 9.5.0 for MacOS, GraphPad Software, San Diego, California USA).

How the 3D Telemedicine MDT enhanced the patient journey

Specific subjective benefits of the 3D Telemedicine International MDT are detailed in **Supplementary Table 1,** and **Flowchart 2**

Patient and Clinician Questionnaire Feedback

Pooled data indicate high values for satisfaction 84.3/100, overall quality (TUQ) 127.3/147, and usability (SUS) 83.2/100 **(Table 1).** Specific questions regarding the 3D International MDT were likewise rated highly, with patient benefit 4.54/5, teaching 4.89/5 and drawing function to explain operations 4.85/5.

Participant Comments

Subjective interview feedback **(Table 2)** included comments such as:

"an amazing undertaking which makes a huge difference to our ability to plan and then follow up complex patients overseas."

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"ability to use expertise from all over the world to help staff and patients in resource-poor settings is fairly game changing."

"It was a privilege to be involved at the outset of what I am sure will be a large part of informed discussion for patients in remote areas all over the world in the future. It also fosters engagement with professionals who might be many thousands of miles remote from each other, which can only benefit patients."

Table 2

Comparison between Ghana and UK data

Ghana patient data (n=4) were compared with our previously published UK patient data [1]. No differences were seen between patient groups in Ghana and Glasgow for measures of satisfaction, TUQ and SUS **(Supplementary Table 2).**

Discussion

The 3D Telemedicine international MDT: a novel innovation to enhance overseas surgical collaborations

Here, we demonstrate a proof-of-concept of real-time 3D Telemedicine in an International MDT setting in a LMIC context. Potential benefits include surgical and anaesthetic planning, increased safety, improved inclusion and education of patients, facilitation of Global South and Global North surgical team discussions, and better team integration. Although this is emerging technology which needs further validation in a LMIC context, it is a promising approach that may encourage *"expertise from all over the world to help staff and patients in resource-poor settings*".

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Potential advantages of a 3D Telemedicine system over standard 2D Telemedicine

Our research group has previously demonstrated the clinical advantages of 3D Telemedicine over standard 2D Telemedicine – including validated patient metrics for satisfaction, quality and realism of consultation. Fundamentally, 3D Telemedicine brings the remote consultation closer to the experience of a face-to-face consultantion than 2D Telemedicine. Practical benefits extend to the ease of examining difficult anatomical areas such as the back of the head or body, the ability to examine multiple joints without patient re-positioning, and ease of positioning the patient with limited mobility - such as severe burns contractures - who is unable to move for the camera. Importantly, given the real-time nature of the 3D Telemedicine system, both the patient and LMIC clinical team are fully engaged in surgical discussions. Non-specific benefits of a real-time 3D Telemedicine MDT may include facilitating surgical planning, integration of Global North and South teams, logistic planning for equipment and operative time, skills planning, real-time assessment of range-of-motion including airway planning (neck and mouth opening), and allowing patients to meet both surgical teams in advance of the visit (Further details outlined in **Table 1**). However, as this was a proof-of-concept study to demonstrate the feasibilty and early clinical benefits of the international real-time use of a 3D Telemedicine system only, further research is required to extrapolate clinical benefits over 2D Telemedicine in an LMIC context, assess feasibilty of integration into local healthworks, and determine cost-benefit ratios.

(Flowchart 1).

Current use of Telemedicine in Overseas Surgical Visits

The present study focuses on the innovation associated with 3D Telemedicine, but to put this into context, telemedicine of any form remains a relatively underutilised resource in overseas surgical collaborations. Although used successfully in Noma, other forms of pre-surgical planning including tele-proctoring with smartglasses, and humanitarian disaster relief [11-14], a recent scoping review by Owalabi et al in 2022 found that telemedicine was used relatively infrequently pre-operatively in the LMIC patient care pathway (only 5.6% studies included pre-operative assessment). This included research studies on overseas visits, in-country planning, provider-to-provider care, and follow-up. Nonetheless, the global infrastructure, human resources support and healthcare frameworks required to support Telemedicine already exist in many regions - supported by governmental, non-governmental organisations (NGOs) and charities such as Swinfen Telemedicine [15] and Réseau en Afrique Francophone pour la Télémédecine (RAFT) [16]. In Ghana, mixed models such as the Ghana Telemedicine project (a joint programme between the Ghana Health Service, Ministry of Health and Novartis Foundation) exist, supported by an optical fibre backbone currently running along the Eastern corridor of Ghana [17]. Together these data highlight that there is scope, enthusiasm and infrastructure to further integrate telemedicine into the pre-surgical care pathway both for overseas visits and in-country health frameworks.

Patient Education and Consent

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Aside from pre-visit patient planning on overseas surgical collaborations, there are few data in the published literature regarding the consent and education of patients during such visits, with the traditional approach being discussion between doctor and patient. However, "health literacy" - the ability to understand, act on and communicate health information - is inadequate or problematic in 62.8% of the population in Ghana [18]. Our parallel research work shows that taking a purely visual approach to patient education in reconstructive surgery may overcome this "literacy gap" by conferring significant benefits in understanding, education and motivation [19]. Although Holoportation™ technology is intended for use as a communication device only, the ability to draw operations on patients allows the clinician to explain an operation on the actual patient's body, using purely visual means. In doing so this may obviate the "literacy gap", aid patient understanding, and provide a "personalised medicine" approach to surgical planning. Notably, all patients on subjective questioning found the 3D Telemedicine pre-operative visit to be very helpful in terms of understanding the proposed operation.

Telemedicine for improving Clinical Follow-up & delivery of post-operative care

Systematic reviews suggest a follow-up rate following overseas surgical visits of 56%, although this is likely to be a significant overestimate as most published studies do not report follow-up figures [20]. Complication rates of 22% have been reported, highlighting the necessity for careful follow-up [20]. Other key parameters that should be considered as integral to the follow-up process and patient journey include delivery of physiotherapy, planning for secondary surgery, and management of complications including appropriate medication eg neuropathic pain. Telemedicine, such as the 3D Telemedicine International MDT described here, allows a forum for review of complications, assessment of post-

operative function, delivery of physiotherapy, and patient education. It also acts as a forum for de-briefing Global North and South teams and cross-transfer of clinical knowledge, reinforcing the partnership nature of these collaborations.

Health Framework Support and Sustainable Partnerships

Korle Bu Teaching Hospital, Ghana and the Canniesburn Plastic Surgery Unit, UK, have a longstanding, sustainable partnership extending over 30 years, involving cross-border exchange of staff, teaching, resource sharing, and skills transfer. Support for this project at Health Framework level came from the Ministry of Health, Ghana, and the West of Scotland NHS Innovations Hub, UK. A research team from Ghana was integral to the development and implementation of this project, to ensure ownership and fit-to-context of the 3D Telemedicine system. Researchers from Ghana were embedded within the UK research team for a period of 2 years during the development stage. Together, this approach helped to foster successful clinical and research partnerships, adhering to principles suggested by international groups such as the British Foundation for International Reconstructive Surgery (BFIRST) [21].

Fit to context: costs, technology and infrastructure

The 3D Telemedicine system has been developed with local stakeholders in Ghana since discussions commenced in November 2019, with support from the Ministry of Health, Ghana. Patient development pivoted to Glasgow in 2020 due to constraints on global research imposed by the Covid Pandemic, but critically the Ghana research team were embedded in Glasgow during this time for a 2 year period. Financial implications of novel technology were considered during development, and it therefore utilises off-the-shelf

components, at a cost-equivalent of a video conferencing suite. Cost-quality constraints will progress inexorably towards favouring higher quality at lower cost, and it is therefore important to demonstrate feasibility, usability and fit to context at an early stage in the development cycle. Technical limitations revolve primarily around availability of high speed internet in LMIC, and "last mile" infrastructure connections to Ghana's fibre-optic backbone network. In Ghana the availability of mobile internet solutions (such as MTN Turbonet) overcomes many of these issues. Future coverage by space based communication technology (low earth orbit satellites that by virtue of being closer to earth, reduce latency) such as StarLink, may also provide an elegant solution to "last mile" constraints in LMIC, with current rollout commencing in West Africa in 2022. Our current research trajectory involves the use of a mobile 3D Telemedicine solution as we discuss below. Notably, remote access and control of Ghana's 3D Telemedicine system from Glasgow only requires the use of non-specialist commercial broadband.

Health Frameworks and Increasing Access to Care

Loss of patients to follow-up is often erroneously attributed to lack of patient engagement. In Ghana, the greatest negative predictor of health-care utilization is distance [22]. Given that most of Ghana's specialist services, including plastic surgery, is centralised in Accra and Kumasi, many patients do not return for follow up care, physiotherapy, and planning of secondary surgery. Ghana has 22 plastic surgeons (Dec 2022) servicing a population of 28.8 million—over an order of magnitude less than the 1 per 80,000 recommended in the United Kingdom [23]. Increasing access to care requires fundamental changes to health frameworks, and in low-resource settings the upscaling of specialist workforce is not a tenable solution. Alternative models include decentralization of care, but this may come at the expense of

high-quality care. For example in burns, superior outcomes have been consistently found in burns centers rather than in peripheral hospitals [24]. We have previously proposed a mixed model approach incorporating decentralization of complex care services, but leveraging eHealth solutions such as 3D telemedicine, that may mitigate the need for specialist centres by providing direct round-the-clock access to specialist expertise [2] Telehealth oversight from the National Reconstructive Plastic Surgery and Burns Centre, Accra, may consequently enhance quality of local reconstructive care through skills transfer, capacity building, expedite urgent transfers, and incentivize patient healthcare utilization. Our previous research quantified inequitable access to care by utilising geospatial mapping created for the Malaria Atlas Project, using data sources provided by Open Street Map and Google that allow travel times to be quantified at a spatial resolution of 1 × 1 km [25] By extending specialist reconstructive care coverage through 3D Telemedicine to 8 district hospitals in rural Ghana, we illustrated the potential to increase population coverage within 1-hour travel time from 29.9% to 45.3% - equivalent to an additional 5.1 million people coverage [2]. Our future research focuses on a mobile 3D Telemedicine system. The benefits of such an approach are twofold. Firstly, this would obviate need for “last mile” internet infrastructure requirements to rural hospitals. Secondly, it would utilise an existing, culturally appropriate, and successful model of patient engagement that has been previously used for in-country Cleft lip projects. This relies on radio broadcast and publicity at local markets – as many villagers in remote areas will come to the local markets for shopping, who would otherwise remain entirely unaware - prior to the scheduled arrival of the mobile healthcare services.

The Lancet Commision on Global Surgery

The 2015 Lancet Commission on global surgery highlighted the significant unmet need of safe access to surgical care in low and middle-income settings, with rates highest in eastern, western, and central sub-Saharan Africa. Improving surgical services in these countries saves lives and urgent investment in human and physical resources is needed [26]. Implementing a 3D Telemedicine MDT facilitates involvement from an international team of surgeons and anaesthetists to collaborate with local clinicians and improve both peri-operative and surgical care of complex conditions, not limited to plastic surgery. Improving access to surgical care, when 58% of the population in sub-Saharan Africa live in rural areas (compared to 16-17% in the UK and USA) [27], is key to reducing mortality from surgical conditions and improving access to specialised reconstructive care. The transportability of the 3D Telemedicine MDT setup may be one solution to this unmet need.

Bias and Limitations

These data present a proof of concept study only, with the inherent limitations related to a small dataset. The data presented here demonstrate technical feasibilty and early clinical efficacy, but require further research in a LMIC context. Technical improvements in 3D resolution, lag and stability between Ghana and the UK are part of the current research pathway, and a randomised controlled trial is underway in the UK to provide evidence of clinical efficacy.

Summary

This study provides the first proof-of-concept of a 3D Telemedicine International MDT, demonstrating the potential for adoption of novel technology to enhance overseas surgical

visits. Importantly, given the real-time nature of the 3D Telemedicine system, both the patient and LMIC clinical team are fully engaged in surgical discussions. Arguably this provides greater opportunity for education, optimising shared decision making, and pre-surgical reflection on treatment plans (by patients and surgeons), than when time-constrained surgical visits require near-to-treatment decision making that differs from routine elective practice. Specific benefits related to this innovation may include:

1. Global pre-operative discussion of the complex reconstructive patient in 3D – allows expert opinion on complex cases with the ability to view the patient in 3D and in real-time, potentially allowing improved surgical and functional assessment

2. Patient education and inclusion – facilitates patient involvement in surgical discussions and may overcome the "literacy gap" when using patient's own body in 3D to explain operations.

3. Follow up and delivery of allied services in LMIC – future delivery using a 3D Telemedicine mobile solution to increase both rural follow up, delivery of allied services such as physiotherapy, and improving access to care in LMIC.

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Ethical Approval

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Ethics approvals (KBTH-IRB 000218/2022) obtained from Ethics Board of Korle Bu Teaching Hospital, Ghana. Participants consented in writing. Patient data controlled by Korle Bu Teaching Hospital.

Conflict of Interest

The authors have no disclosures.

Patient Consents

Consent has been obtained for publication of identifiable photographs and videos for all individuals including patients and clinicians.

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Figure Legends

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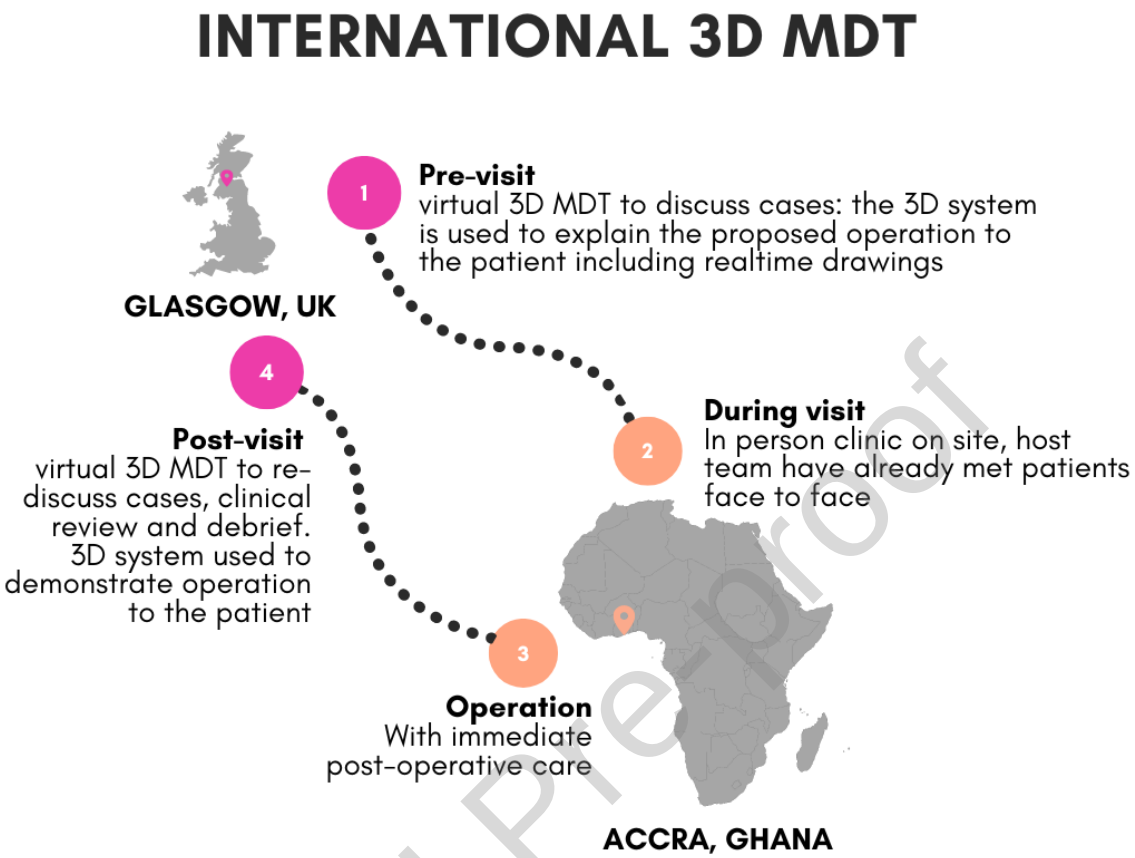

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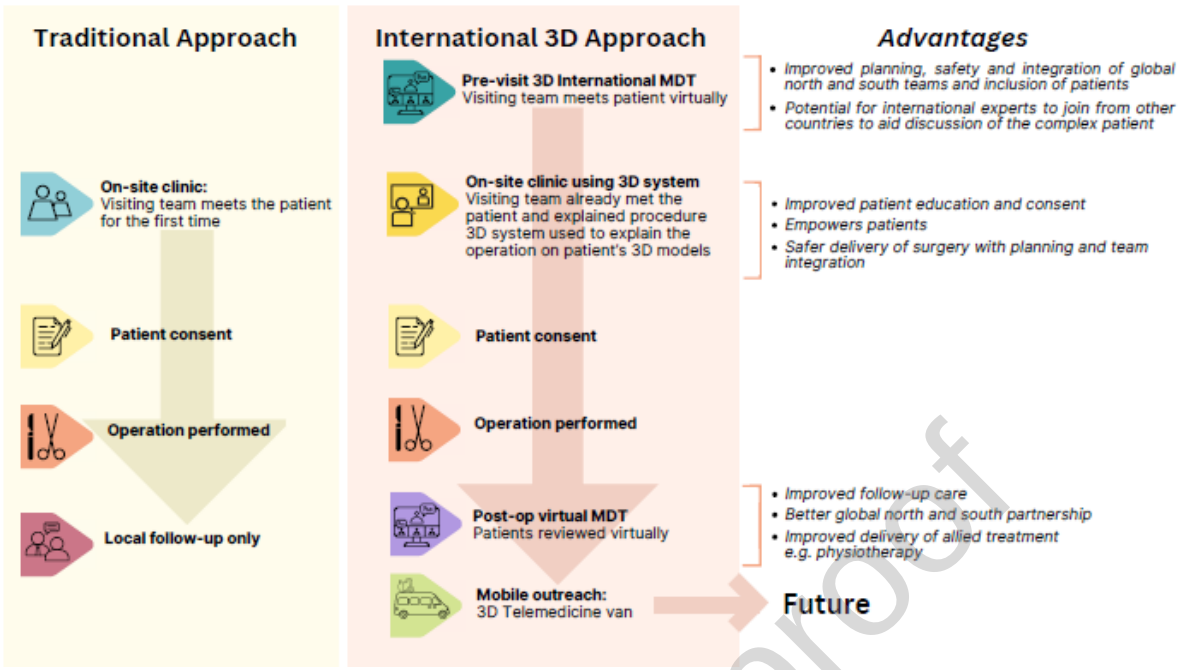
Flowchart 1: Illustration of the patient journey. This consists of pre-visit 3D telemedicine international MDT; on-site use of 3D telemedicine system with patient; operation; and post-visit 3D telemedicine international MDT. Future use of a mobile 3D telemedicine will be used to facilitate rural follow-up and increase access to care in LMIC. (Map image courtesy of Free Vector Maps, https://freevectormaps.com/world-maps/WRLD-EPS-01-0015?ref=atr)



Flowchart 2: Paradigm shift in approach to overseas surgical visits. Perceived advantages of an international 3D Telemedicine approach versus the traditional approach to overseas surgical visits.

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Figure 1: The Holoportation 3D Telemedicine Clinic in Korle Bu Teaching Hospital, Ghana.

A patient with ameloblastoma of the mandible talks with Levi Ankrah, Consultant Plastic Surgeon. They are surrounded by 10 Kinect cameras and the patient can view the 3D images on the screen in front of them.

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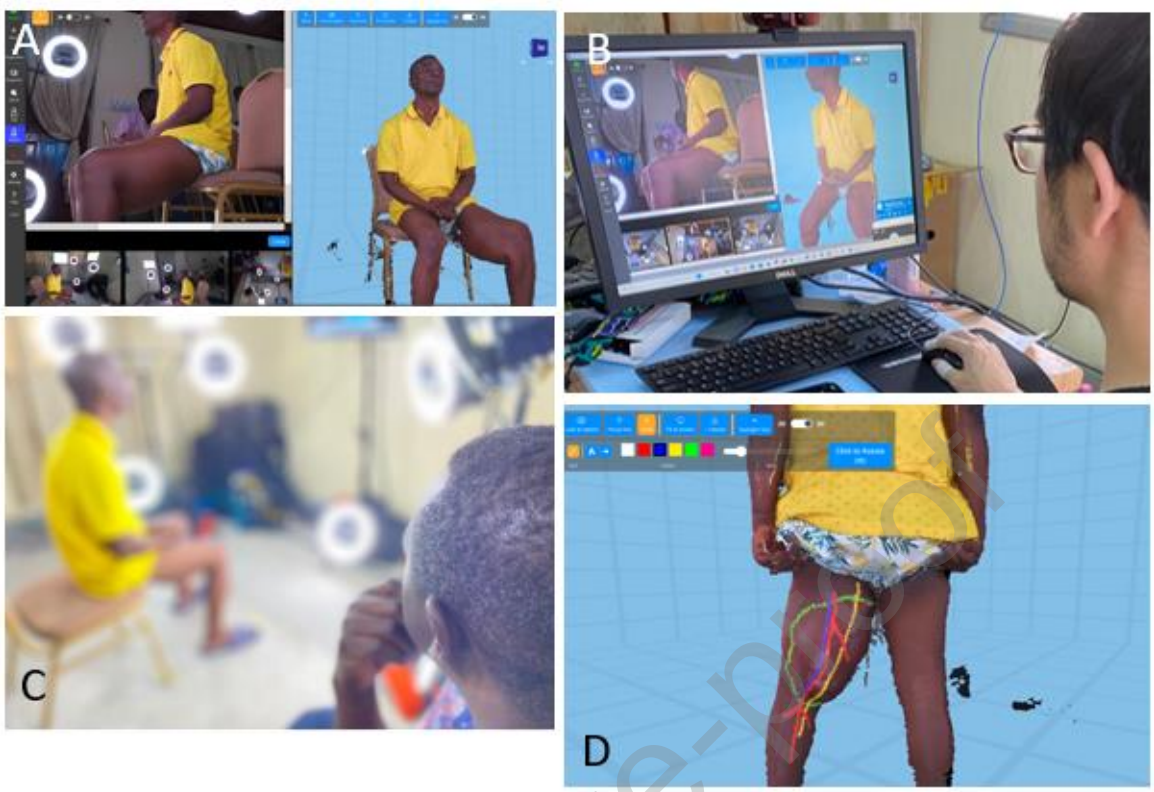

Figure 2: A) 3D Telemedicine viewer screen – this shows the real-time 3D model on the right side of the screen, and a 4K view from one of the multiple cameras on the left side of the screen. **B)** The 3D system in use, with the model controlled by the clinician using a mouse, similar to a CT or MRI scan viewer. **C)** Patient sitting in the 3D rig as one of the Ghana surgeons looks on **D)** Drawing on the 3D model to illustrate the tumour (green outline), vessels and the sciatic nerve (yellow) and why the nerve cannot be preserved during the tumour resection.

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Figure 3: Pre-visit Glasgow-Ghana international 3D Telemedicine MDT. Surgical and anaesthetic team in Glasgow, UK meet remotely with a patient with a maxillary defect in Accra, Ghana. The Ghana surgical team are in the clinic room with the patient.

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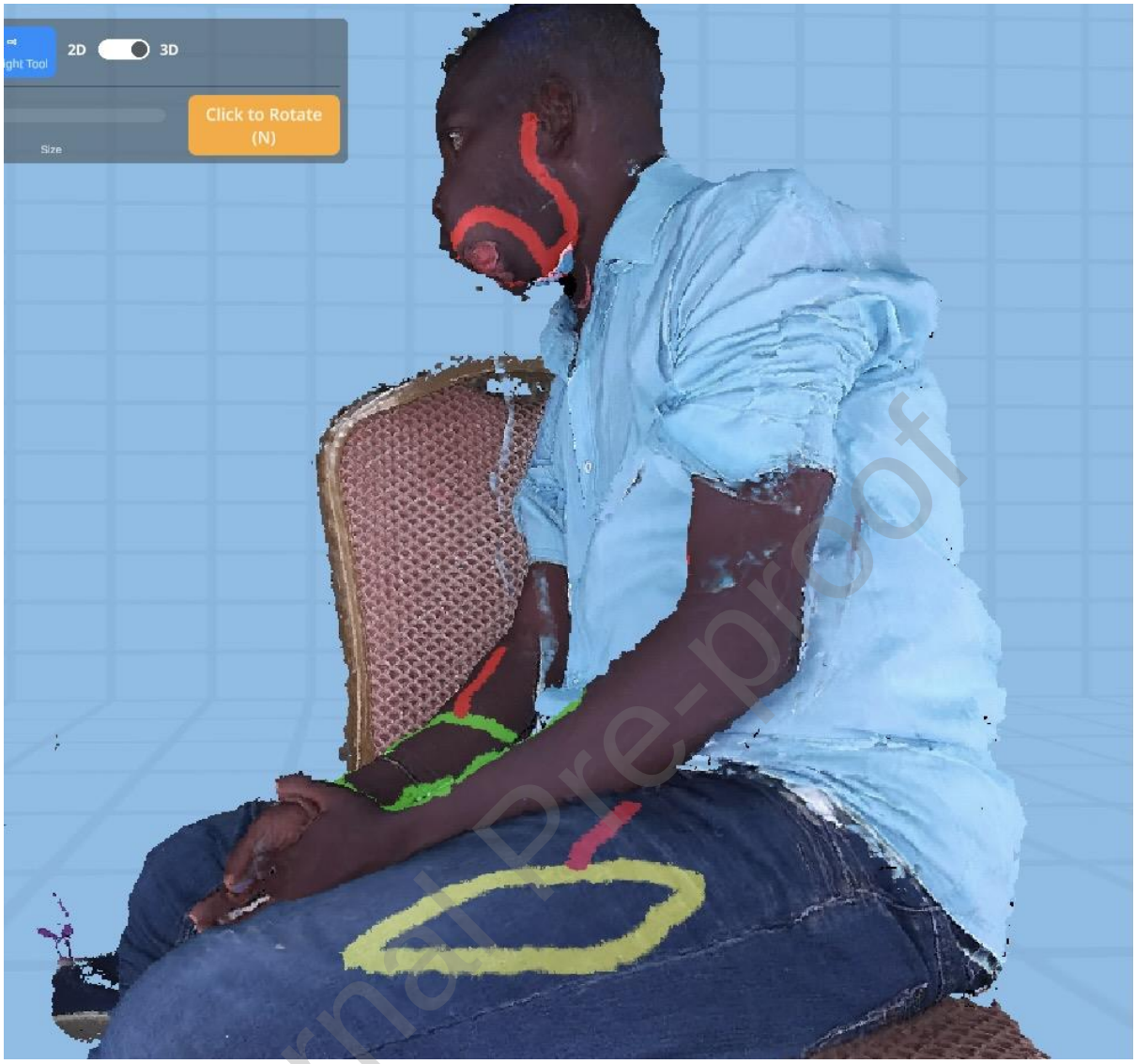

Figure 4: Ghana pre-operative 3D clinic. The doctor uses the system to draw the incisions for resection of ameloblastoma on the patient's head and neck (red outline), and proposed options for radial forearm (green outline) and anterolateral thigh flaps (yellow outline).

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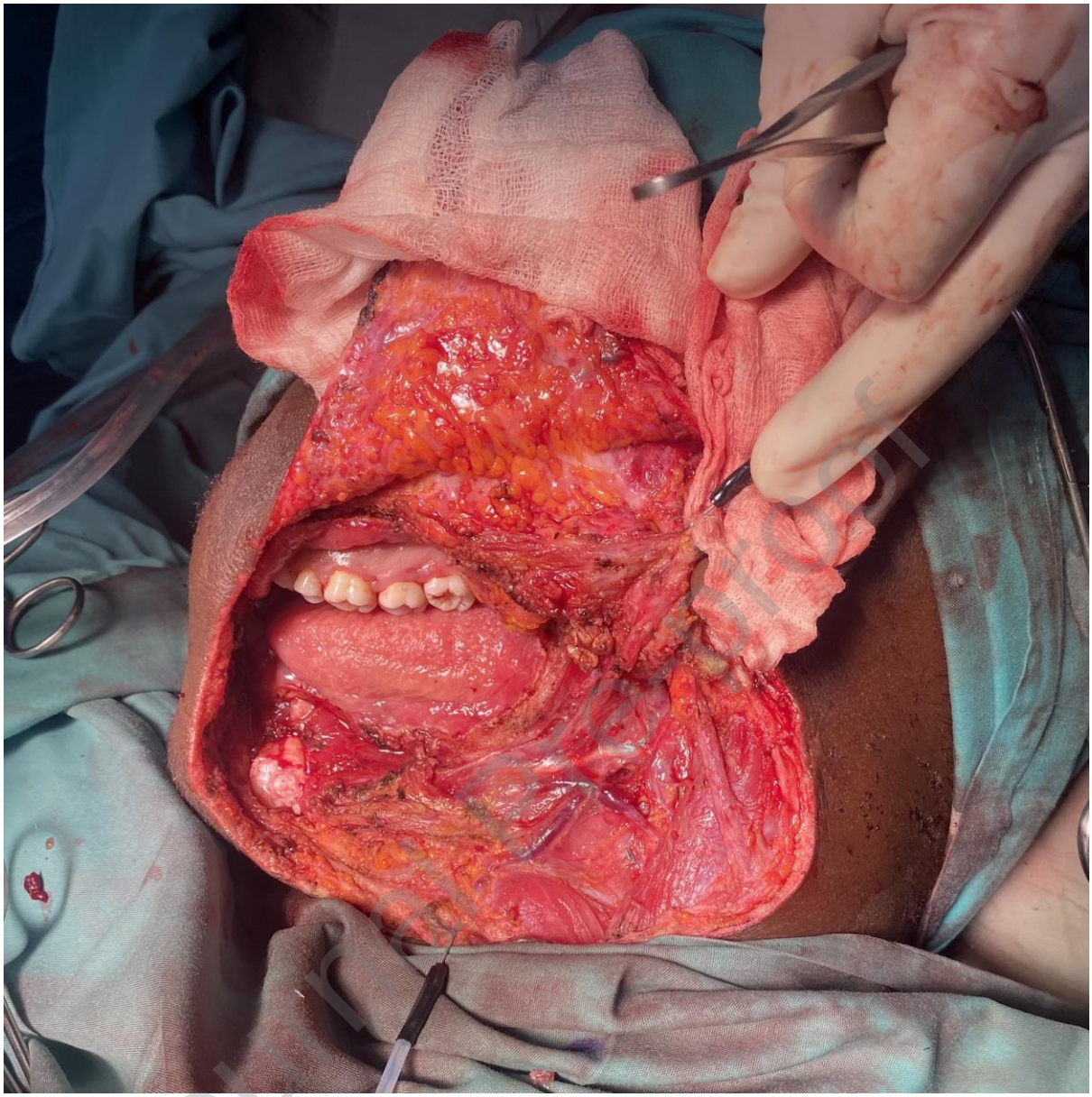

Figure 5: Intra-operative. Mandibular resection defect. Temperomandibular joint previously excised.

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Figure 6: Intra-operative. Dr Elliot Aboham, Consultant Plastic Surgeon at Korle Bu Teaching Hospital, raising ALT flap

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Figure 7. Intra-operative. Flap inset and anastamosed to the facial vessels.

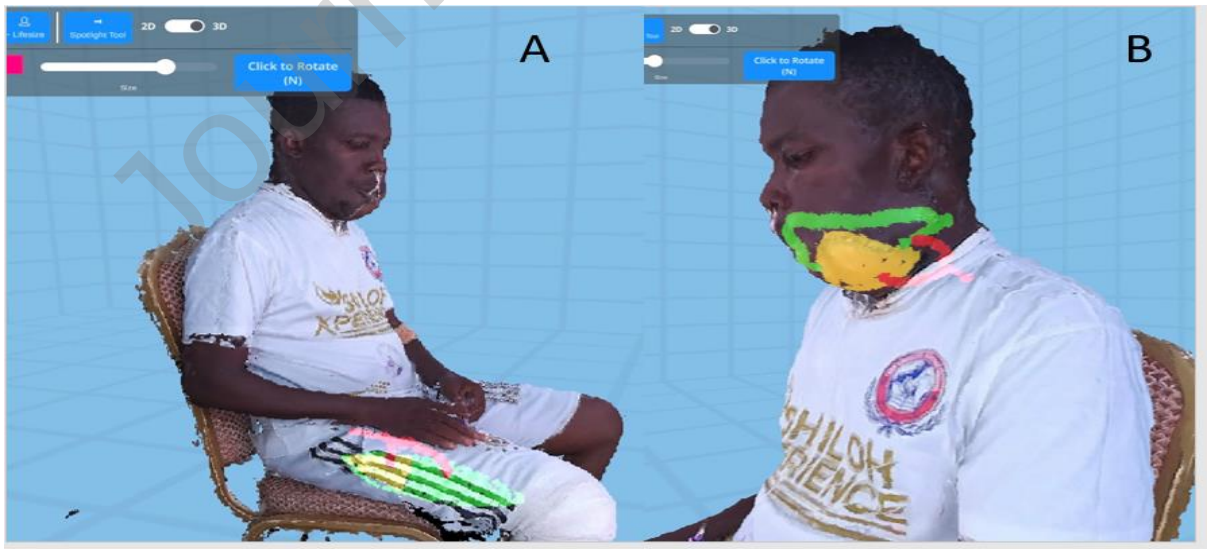

Figure 8. Post-visit Glasgow-Ghana international 3D Telemedicine MDT. A) One week post-visit the patient with ameloblastoma and ALT flap is reviewed in the Holoportation clinic.

This allows the Glasgow and Ghana clinical teams to examine him in 3D, and assess neck and mouth opening. The ALT flap is drawn on the patient's thigh to explain the operation in more detail. The extra-oral skin paddle is highlighted in yellow and the intra-oral component in green. **B)** The flap design is shown in-situ on the patient's face, with the extra-oral component in yellow and the intra-oral component outlined in green.

a

Supplementary Video 1: Patient Journey through the 3D International MDT. This video follows a patient the mandibular ameloblastoms and illustrates the pre-op 3D assessment, operation and post-operative 3D MDT. Note that some segments are sped up for the purposes of brevity in this video.

Supplementary Figure Legends

Supplementary Figure 1: Ghana pre-operative 3D clinic. John Biddlestone, Consultant Plastic Surgeon, examines the patient with ameloblastoma.

Supplementary Figure 2. Ghana pre-operative 3D clinic. In the background is the Holoportation clinic and patient.

Supplementary Figure 3. Intra-operative. ALT flap with extra-oral skin paddle on left based on the oblique branch, and intra-oral skin paddle on right with portion of vastus lateralis based on longitudinal descending branch.

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Supplementary Figure 4. Post-visit Glasgow-Ghana international 3D Telemedicine MDT.

The team in Glasgow, seen on the panels on the right, can control the 3D system remotely from Glasgow. Here they are examining a patient with maxillary defect who underwent radial forearm flap reconstruction. The procedure is explained to the patient by drawing on his 3D model, with the flap highlighted in green.

Table 1: Clinician and Patient Outcomes

	Scale	**Ghana Patients (n=4)**	**Ghana Clinicians (n=4)**	**Glasgow Clinicians (n=5) Mean [95% CI]**	**Overall (pooled data)**
Satisfaction	0-100 Visual analogue scale	87.50 [82.55, 92.45]	88.25 [73.30, 103.2]	78.60 [73.99, 83.21]	N=13 84.31 [79.98. 88.63]
Mental Effort Rating Scale	1-9 Likert scale, where 1 is very, very low mental effort and 9 is very, very	N/A	2.5 [0.91, 4.09]	3.6 [1.93, 5.27]	N=9 3.11 [2.14, 4.09]

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	high mental effort				
Patient Benefit "How much benefit do you think the patient will gain from the international MDT discussion?"	1-5, where 1 is worst and 5 is best	4.25 [2.73, 5.77]	4.75 [3.95, 5.55]	4.6 [3.92. 5.28]	N=13 4.54 [4.14, 4.94]
Teaching "Do you think this system would be of benefit for international clinical teaching?"	1-5, where 1 is worst and 5 is best	N/A	4.75 [3.95, 5.55]	5 [5.0, 5.0]	N=9 4.89 [4.63, 5.15]
Lag "Was the lag/ delay between using controls	1-5, where 1 is worst (very noticeable) and 5 is best	N/A	3 [1.7, 4.30]	3.2 [1.58, 4.82]	N=9 3.11 [2.30, 3.91]

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and 3D model noticeable?"	(not noticeable)				
Draw function "Was the drawing function helpful to explain operations to patients?"	1-5, where 1 is worst and 5 is best	5 [5.0, 5.0]	5 [5.0, 5.0]	4.6 [3.49, 5.71]	N=13 4.85 [4.51, 5.18]
Telehealth Usability Questionnaire (TUQ)	0-147	124.5 [94.18, 154.80]	130.0 [116.1, 143.9]	N/A	127.3 [115.5, 139.0]
System Usability Scale (SUS)	0-100	76.50 [54.24, 98.76]	90.0 [80.63, 99.37]	N/A	83.2 [73.0, 93.5]

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Table 2: Patient and Clinician comments

Comments
"a great concept. It is quite easy to manipulate and the drawing function is a very good touch"

"…patients were quite intrigued by what they saw. I feel they were fascinated and it gave a better understanding."

"using the system for an international MDT improves patient access to a range of international experts for different conditions"

"This is an amazing undertaking which makes a huge difference to our ability to plan and then follow up complex patients overseas."

"The teaching possibilities are also exciting."

"Ability to use expertise from all over the world to help staff and patients in resource-poor settings is fairly game changing"

"ability to communicate and perform face to face consultation and do real time screenshot and drawing on patient to explain the procedure and surgery involved"

"very grateful to be part of this exciting and worthwhile project"

"drawing function superb"

"offers a high level of realism and enhanced communication with patient and surgical colleagues"

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"It was a privilege to be involved at the outset of what I am sure will be a large part of informed discussion for patients in remote areas all over the world in the future. It also fosters engagement with professionals who might be many thousands of miles remote from each other, which can only benefit patients."

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