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

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Summary 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 before, during, and after an overseas surgical collaboration.
Methods: A proof-of-concept international 3D MDT clinic took place in November 2022, between the Canniesburn Plastic Surgery Unit, UK, and the National Reconstructive Plastic

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2. American Society of Plastic Surgeons meeting, Atlanta, USA, October 2021.
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4. Future Surgery Show, London, November 2021.

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Three-dimensional;
Surgery, Plastic

Surgery and Burns Centre, Korle Bu Teaching Hospital, Ghana. The 3D system was utilised 1) previsit 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 the team and patients.

Results: Four Ghana patients were followed through their patient journey (mandibular ameloblastoma, sarcoma thigh, maxillary tumour, sarcoma back). Thirteen participants (four patients, four Ghana clinicians, and five 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: This novel technology has the potential to enhance the delivery of overseas surgical visits to low-to-middle-income countries, 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.

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 the 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-centred 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.[1,3] Testing focused on the assessment of validated patient metrics in comparison with 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 multidisciplinary team meetings (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 the Ethics Board of Korle Bu Teaching Hospital, Ghana. Participants consented in writing. Patient data controlled by Korle Bu Teaching Hospital.

Approach and preliminary work

The 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 the USA. Details of the development of 3D Telemedicine involving patient and clinician feedback testing, safety and reliability, and a cohort trial are described in our previous publication.[1] Importantly, the 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 five visiting surgeons and six anaesthetists from Canniesburn Plastic Surgery Unit, UK. Four patients were included in the 3D Telemedicine International MDT proof-of-concept trial, including a maxillary squamous cell carcinoma, 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 (Supplementary Table 1).

Methods, setting, and patient journey

The 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, UK). The 3D Telemedicine system in Ghana could be controlled remotely from Glasgow using a commercial broadband connection at 5–10 megabits (Mbps) (Figure 2).

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

1) **Before international travel in Glasgow** – to facilitate surgical planning and real-time patient assessment (Figure 3).
2) **Preoperatively on-site in Ghana** – to aid in patient education and explain the proposed operation to patients (Figures 4–7, Supplementary Figures 1–3).
3) **Postoperatively 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.**

Supplementary material related to this article can be found online at doi:10.1016/j.jhazmat.2020.124016.

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 the overall quality of the system and consisted 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).

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.

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.*"

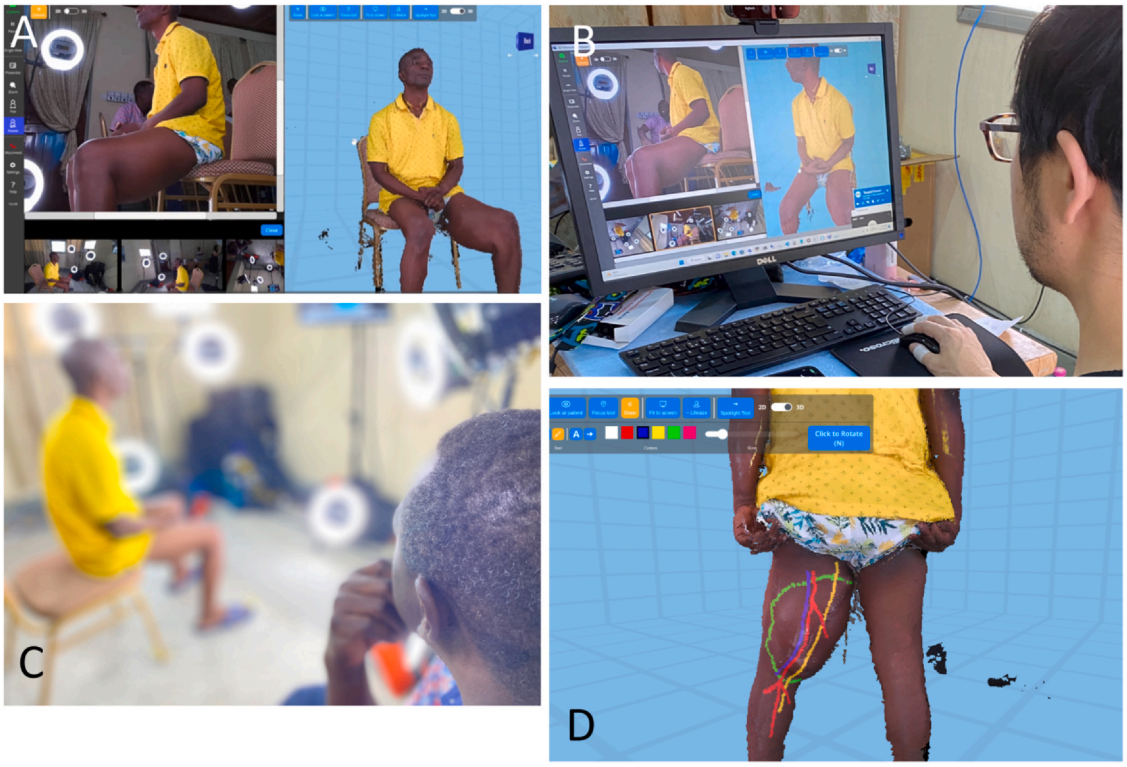
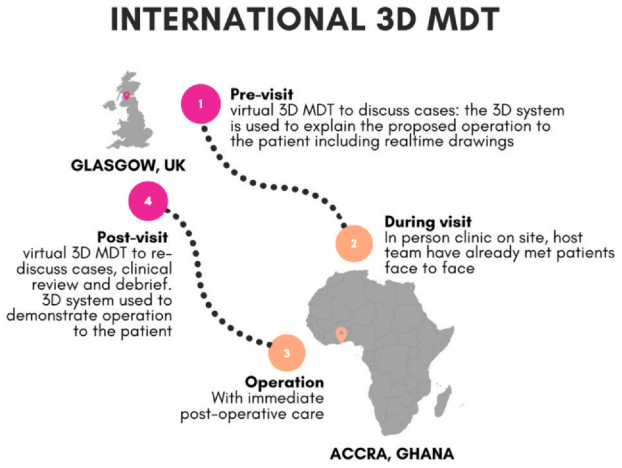


Figure 2 A) 3D Telemedicine viewer screen – this shows the real-time 3D model on the right side of the screen and a 4 K view from one of the multiple cameras on the left side of the screen. B) The 3D system in use, with the model controlled by the clinician using a mouse, is similar to a CT or MRI scan 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.



Flowchart 1 Illustration of the patient journey. This consists of pre-visit 3D Telemedicine international MDT; on-site use of 3D Telemedicine system with the patient; operation; and post-visit 3D Telemedicine international MDT. Future use of 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).

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

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

"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

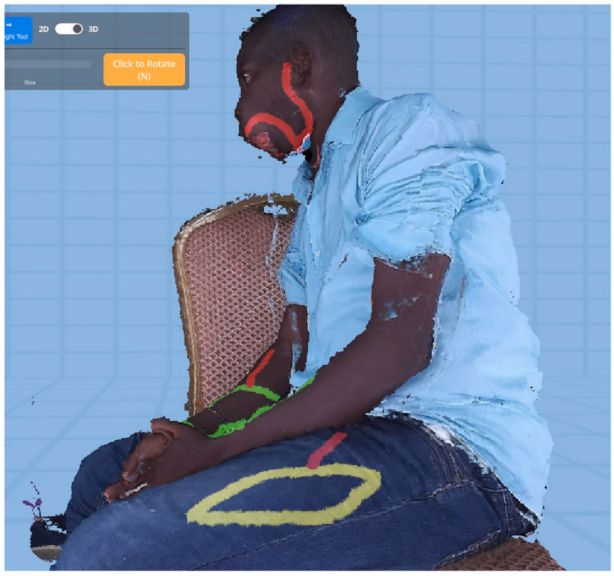


Figure 4 Ghana pre-operative 3D clinic. The doctor uses the system to draw the incisions for resection of ameloblastoma on the patient's head and neck (red outline), and the proposed options for radial forearm (green outline) and anterolateral thigh flaps (yellow outline).

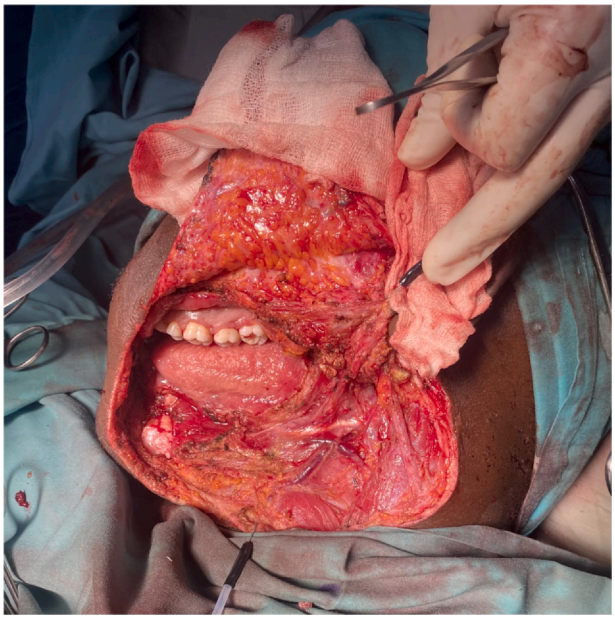


Figure 5 Intra-operative. Mandibular resection defect. Temporomandibular joint previously excised.

might be many thousands of miles remote from each other, which can only benefit patients."

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).

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

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

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 an 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 an emerging technology that needs further validation in an 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*".

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

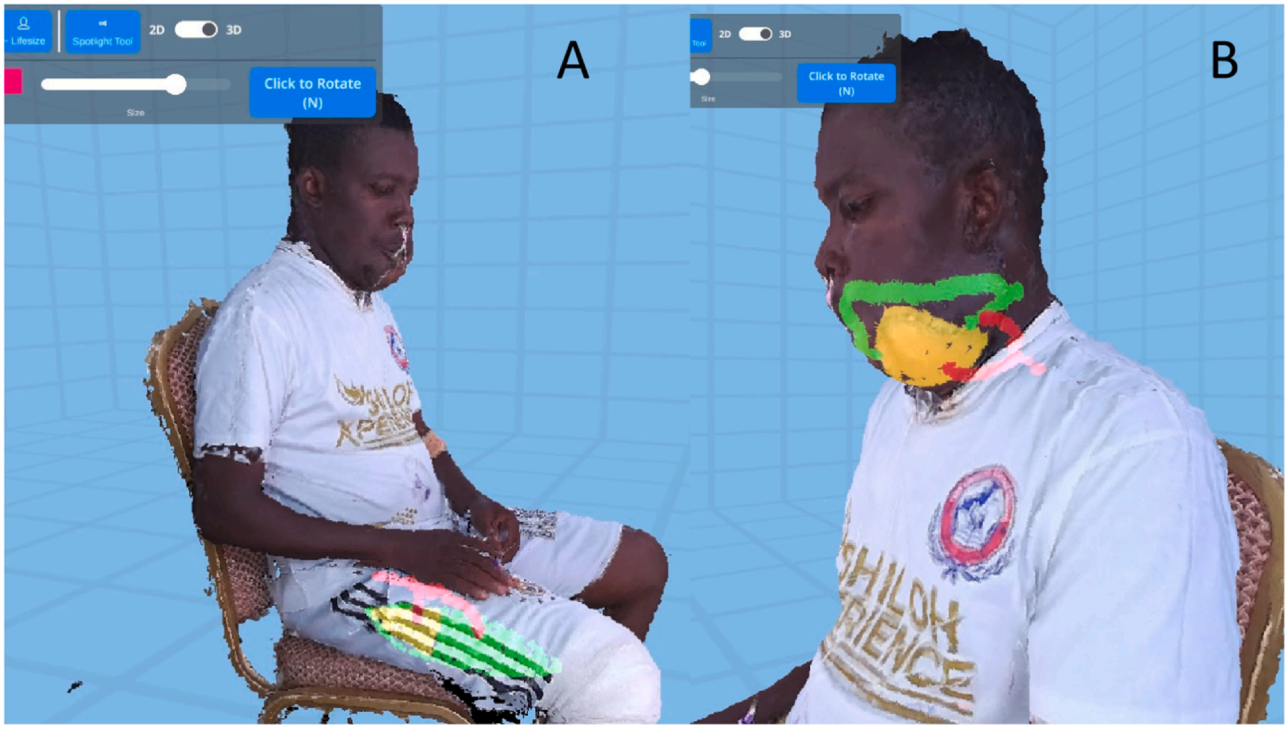
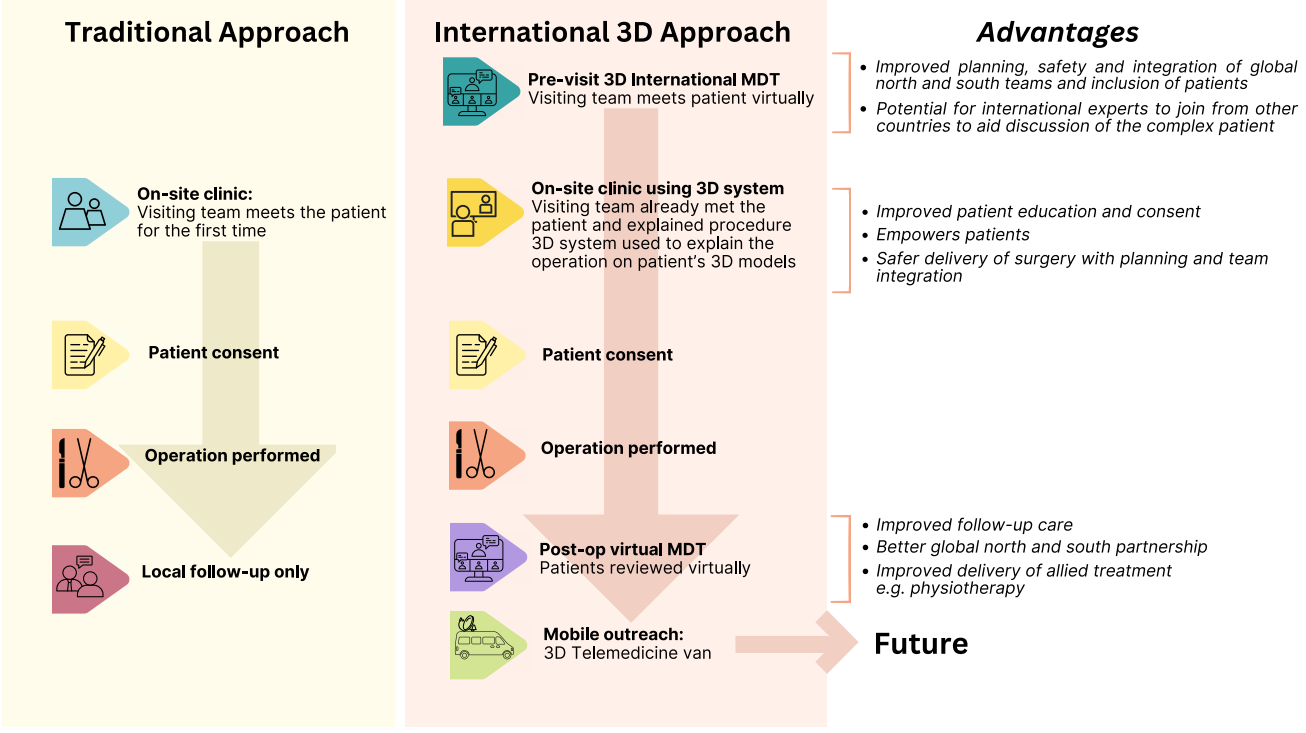


Figure 8 Post-visit Glasgow-Ghana international 3D Telemedicine MDT. A) One week post-visit, the patient with ameloblastoma and ALT flap is reviewed in the Holoportation clinic. This allows the Glasgow and Ghana clinical teams to examine him in 3D, and assess the neck and mouth opening. The ALT flap 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.



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.

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 high mental effort	N/A	2.5 [0.91, 4.09]	3.6 [1.93, 5.27]	N = 9 3.11 [2.14, 4.09]
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 and 3D model noticeable?"	1–5, where 1 is worst (very noticeable) and 5 is best (not noticeable)	N/A	3 [1.7, 4.30]	3.2 [1.58, 4.82]	N = 9 3.11 [2.30, 3.91]
Draw function "Was the drawing function helpful in explaining 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]

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"
"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."

remote consultation closer to the experience of a face-to-face consultation 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 repositioning, and the 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. Nonspecific 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 are outlined in Table 1). However, as this was a proof-of-concept study to demonstrate the feasibility 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 the feasibility of integration into local health works, and determine cost–benefit ratios.

Current use of telemedicine in overseas surgical visits

This 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 presurgical planning, including teleproctoring with smart glasses, and humanitarian disaster relief,[11–14] a recent scoping review by Owalabi et al[15] found that telemedicine was used relatively infrequently preoperatively in the LMIC patient care pathway (only 5.6% studies included preoperative 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, nongovernmental organisations, and charities such as Swinfen Telemedicine[16] and Réseau en Afrique Francophone pour la Télémédecine.[17] 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.[18] Together, these data highlight that there is scope, enthusiasm, and infrastructure to further integrate telemedicine into the presurgical care pathway both for overseas visits and in-country health frameworks.

Patient education and consent

Aside from previsit 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.[19] 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.[20] 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 preoperative visit to be very helpful in terms of understanding the proposed operation.

Telemedicine for improving clinical follow-up and delivery of postoperative care

Systematic reviews suggest a follow-up rate of 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.[21] Complication rates of 22% have been reported, highlighting the necessity for careful follow-up.[21] 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, for example, neuropathic pain. Telemedicine, such as the 3D Telemedicine International MDT

described here, allows a forum for review of complications, assessment of postoperative function, delivery of physiotherapy, and patient education. It also acts as a forum for debriefing Global North and South teams and cross-transfer 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 the 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 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.[22]

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 because of the constraints on global research imposed by the COVID pandemic, but critically the Ghana research team was 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 to 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 context at an early stage in the development cycle. Technical limitations revolve primarily around the 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 nonspecialist commercial broadband.

Health frameworks and increasing access to care

The loss of patients to follow-up is often erroneously attributed to the lack of patient engagement. In Ghana, the greatest negative predictor of healthcare utilisation is distance.[23] Given that most of Ghana's specialist services, including plastic surgery, are 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 (December 2022) servicing a population of 28.8 million – over an order of magnitude less than the 1 per 80,000 recommended in the UK.[24] Increasing the access to care requires fundamental changes to health frameworks, and in low-resource settings, the upscaling of the specialist workforce is not a tenable solution. Alternative models include the decentralisation 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 centres rather than in peripheral hospitals.[25] We have previously proposed a mixed model approach incorporating the decentralisation 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 the quality of local reconstructive care through skills transfer, capacity building, expedite urgent transfers, and incentivise patient healthcare utilisation. 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.[26] By extending specialist reconstructive care coverage through 3D Telemedicine to eight 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 the need for "last mile" internet infrastructure requirements for 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 broadcasts 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 – before the scheduled arrival of the mobile healthcare services.

The Lancet commission on global surgery

The 2015 Lancet Commission on Global Surgery highlighted the significant unmet need for 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.[27] Implementing 3D Telemedicine MDT facilitates involvement from an international team of surgeons and anaesthetists to collaborate with local

clinicians and improve both perioperative 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 with 16–17% in the UK and USA),[28] 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 feasibility and early clinical efficacy but require further research in an 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 the 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 a greater opportunity for education, optimising shared decision-making, and presurgical 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 the following.

1. **Global preoperative discussion of the complex reconstructive patient in 3D** – It 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** – This facilitates patient involvement in surgical discussions and may overcome the "literacy gap" when using the 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.

Ethical approval

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

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Declaration of Competing Interest

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Appendix A

3DTM (3D Telemedicine) Collaborative Research Group

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Appendix B. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.bjps.2023.10.130.

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