Evaluating 3D technologies for upper limb prosthesis design, Amman, Jordan

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Introduction
WHO estimates that fewer than 15% of 100 million people worldwide in need of prosthetic and orthotic care (P&O) have access. Conflicts throughout the Middle East have led to an increase in people living with disabilities. People with a unilateral upper limb deficiency commonly seek cosmetic prostheses to help with social stigma, and to provide a support limb for bimanual tasks. The lack of prosthetic clinicians, and prohibitive cost of prostheses in many countries, have led to limited options for patients. In the Middle East, a cosmetic upper limb prosthesis costs $1000-$3000. In 2017, we initiated a 3D project at the MSF Amman Reconstructive Surgery Hospital, aiming to evaluate the feasibility of locally designing, manufacturing and fitting customized 3D printed below-elbow prostheses. The multi-disciplinary team included diverse specialties, including P&O, physiotherapy, occupational therapy and biomedical engineering.

Methods
Each patient first underwent clinical assessments to identify their specific needs. 3D surface scans of the stump and contralateral limb were acquired and used to design each socket and prosthesis. Components were 3D printed at the Irbid Fab Lab from various materials (rigid polylactic acid, semi-flexible co-polyester, flexible thermoplastic polyurethane). After fitting, clinical assessments were performed at various time points to improve the designs and refine the processes. Nine questions from the Orthotic & Prosthetic User Survey were used to determine patient satisfaction.

Ethics
This research fulfilled the exemption criteria set by the MSF Ethics Review Board (ERB) and thus did not require MSF ERB review. It was conducted with permission from Clair Mills, Operational Centre Paris, MSF.

Results
By Feb 2018, 14 patients were enrolled (29% female, 57% <15 yr, 50% trauma-related, 14% lost following enrollment) and 8 were fitted with 9 total prostheses (88% unilateral). Prostheses were worn a mean of 4h 43min per day (SD±3h 6min), with 90% patient satisfaction after 15 days (N=6 patients). Patients reported being satisfied with the weight and comfort of the prosthesis (Mean Satisfaction Score>3.8/4.0). Challenges include long-term durability of components and paint coating. The cost of raw materials to manufacture the 3D printed prostheses ranged from $20-$50.

Conclusion
We have shown the feasibility of locally designing, manufacturing and fitting 3D printed prostheses in this context; the project is ongoing. We are continuing to improve the durability of the prosthesis and to explore the possibility of remote design. Future directions include expansion of the project to other MSF contexts and further collaboration with external rehabilitation centers and technology partners, with the goal of increasing access to P&O care and further developing other potential 3D applications (eg, surgery, burns).

Conflicts of interest
None declared.