

Article

Identifying 3D Printing and Assistive Technology Needs of Rehabilitation Stakeholders

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Abstract

Despite growing interest in three-dimensional (3D) printing for assistive technology (AT), limited research has examined how rehabilitation stakeholders perceive its role within service delivery. This study explored the perspectives of clients who use AT, their care partners, and rehabilitation clinicians to identify perceived affordances and barriers of 3D-printed AT. A qualitative design using purposive sampling targeted individuals with prior exposure to 3D printing. Four in-person focus groups (n = 17) were conducted with nine clinicians, seven clients, and one care partner. One additional semi-structured interview was conducted with a care partner. Data were analyzed using reflexive thematic analysis. Three themes were identified: (1) AT adapts to meet individual needs but encounters practical challenges; (2) 3D printing is an evolving and practical solution to enhance AT access; and (3) education and support are essential to optimize 3D printing service delivery. 3D printing is a feasible complement to traditional AT service delivery when integrated within collaborative, client-centered rehabilitation models. Addressing gaps in education, durability, and structured follow-up processes may enhance the adoption and long-term effectiveness of 3D-printed AT.

Keywords: 3D printing; assistive technology; rehabilitation; service delivery; thematic analysis

1. Introduction

An estimated 2.5 billion individuals globally would benefit from at least one assistive technology (AT) device; however, access to AT remains limited, with only one in ten individuals currently obtaining the devices they need [1]. In the United States (U.S.), AT access is supported through federal policy, including the Assistive Technology Act and its 2022 reauthorization through the 21st Century Assistive Technology Act [2], which emphasizes improving access to, funding for, provision of, education about, and coordination of AT devices and services for individuals with disabilities. Despite existing policies designed to protect AT access, people with disabilities frequently encounter barriers to acquiring AT [3], and insurance coverage for AT is inconsistent and varies widely across payers and regions [4]. When reimbursement for device customization, as well as for required maintenance and repairs, is denied by third-party payers, the burden often shifts to patients and their clinicians, who must seek alternative resources [5].

Rehabilitation professionals, including clinicians from occupational therapy (OT), physical therapy (PT), and speech-language pathology (SLP), play a critical role in facilitating access to AT by evaluating individual needs, recommending appropriate devices,



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and supporting the integration into daily activities, working interprofessionally across rehabilitation settings [6]. Within clinical rehabilitation settings, three-dimensional (3D) printing has emerged as a promising approach to address expanding AT access by enabling rapid, low-cost, and highly customizable device fabrication [7]. Through 3D printing, clinicians can create individualized, low-cost adaptive solutions tailored to clients' needs and preferences, potentially improving both access and outcomes [8–10]. Prior studies have demonstrated the use of 3D printing across a range of settings and AT applications, including orthoses, prosthetics, writing and typing devices, and accessing complex technology such as mobile devices or powered mobility. For example, 3D-printed orthoses have been explored as alternatives to traditional fabrication approaches, with reported benefits related to flexibility, support, comfort, reduced weight, and shorter manufacturing time [11,12]. Within pediatric settings, 3D-printed dynamic upper extremity orthoses designed interprofessionally for children with severe upper extremity impairments address complex functional needs [10]. Other studies have described 3D-printed writing and typing aids, mobile device access adaptations, and personalized assistive devices designed to improve functional access for individuals with physical disabilities [8,9,13].

Customization is a central feature of 3D-printed AT because it allows fit and function to be modified according to the user's environment and preferences. Prior studies have reported that customized 3D-printed devices may improve satisfaction, fit, comfort, or functional performance when compared with standard or commercially available options [14,15]. However, findings are not superior across all device types. For example, customizable 3D-printed finger orthoses may provide comparable satisfaction to commercial splints, while being rated favorably for affordability [16]. These findings suggest that 3D printing should not be framed as a universal replacement for traditional AT, but rather as a flexible option within AT service delivery when personalization, affordability, modification, or limited access to commercial solutions are the user's concerns.

Although existing studies support the feasibility and value of 3D-printed AT, previous literature has focused on specific devices, single cases, technical feasibility, satisfaction, or clinician acceptance. Less is known about how rehabilitation stakeholders experience 3D printing as part of service delivery, including how clients, care partners, and clinicians perceive access, customization, training, follow-up, and implementation within rehabilitation systems.

Human, Activity, and Assistive Technology (HAAT) Model

The HAAT model provides a useful framework for examining relationships by considering the interaction between the individual's needs, the activity, and assistive technology in the multiple contexts of the activity [17]. The HAAT model acknowledges the influence of social, emotional, and environmental factors on performance, assessing both physical limitations and psychosocial impacts. The model not only provides a comprehensive understanding of how AT is integrated into individuals' daily lives but is also applicable across populations served by rehabilitation and can be further explored within the context of 3D-printed devices.

Although prior research has examined device feasibility, satisfaction, clinician acceptance, and specific 3D-printed AT applications, fewer studies have examined how multiple rehabilitation stakeholders understand 3D printing as part of a broader service delivery process. This study addresses that gap by examining the perspectives of clients, care partners, and clinicians within a rehabilitation system and university where 3D printing was already available as a clinical resource. Exploring stakeholder perceptions may provide in-depth knowledge of solution-driven approaches to promoting 3D printing to address its limitations. The objectives of this study were therefore to (1) qualitatively explore

stakeholder experiences and perspectives of rehabilitation stakeholders who utilize AT, including clients, clinicians, and care partners, regarding 3D-printed devices; (2) understand perceived barriers and facilitators within the current service delivery status of 3D-printed devices; and (3) identify opportunities to improve implementation of 3D-printed AT in rehabilitation practice.

2. Methods

2.1. Design

A qualitative design employing reflexive thematic analysis was used via focus groups and semi-structured interviews [18]. Stakeholder participants included rehabilitation clinicians, clients, and care partners affiliated with a rehabilitation system and a partnered university. Within this rehabilitation system, 3D-printed AT services are supported through a centralized 3D printing center located within the inpatient rehabilitation building. The partnered university collaborated with the rehabilitation network during program development by providing consultation and technical support to help establish the 3D printing service. The service includes a virtual catalog of preapproved 3D-printed designs that clinicians may order directly when a pre-designed device meets a client's functional need. After an order is submitted, the device is printed and either delivered directly to the clinician within the inpatient rehabilitation setting or distributed to clinicians at other sites through interoffice mail. When a client may benefit from a customized design, rehabilitation clinicians may consult the 3D printing clinical specialist to determine whether a commercially available device, a modification of an existing design, or a newly developed 3D-printed solution is most appropriate. Customized designs may involve one or more site visits by the 3D printing specialist to observe the client, equipment, environment, and functional needs. Designs are fabricated using available 3D printing technologies and trialed with the client and clinical team. Feedback on fit, usability, safety, durability, and functional performance is used to refine the design through an iterative process that may include multiple revisions as needed. In addition to the rehabilitation network workflow, the partnered university supports community-based access to 3D-printed devices through fulfilled requests coordinated by a campus 3D printing student club in collaboration with the occupational therapy program. Together, these clinical and university-based pathways provided the service-delivery context in which participants gained experience with 3D-printed AT.

The Moravian University Institutional Review Board approved the study's procedures.

2.2. Procedures

Participants were recruited through purposive sampling, to identify individuals with prior exposure to 3D-printed AT within the rehabilitation system and the partnered university 3D printing program. This sampling approach was selected to ensure that participants could speak directly to experiences with 3D-printed AT, including device access, customization, clinical use, barriers, and service delivery processes. Recruitment targeted three stakeholder groups affiliated with the partnership: clients who had used AT and had prior exposure to 3D printing, care partners supporting individuals who used AT, and rehabilitation clinicians from OT, PT, and SLP who had experience with or awareness of 3D-printed AT services. Recruitment occurred via email outreach to individuals associated with the network and the partnered university who had received a 3D-printed device for personal use, as well as to clinicians within the rehabilitation network representing the clinical service lines of OT, PT, and SLP. For individuals residing in a long-term care facility who may have had limited access to email, the researchers approached them in person at the facility. The inclusion criteria for all participants were individuals aged 18 years

or older with prior exposure to 3D printing. Clients were required to use at least one AT device daily and have a disability or rehabilitation history. Care partner inclusion criteria were the provision of emotional, physical, and/or financial support to individuals with a disability, including the parents or guardians of children with disabilities. Clinicians were licensed in their respective professional therapy fields of OT, PT, or SLP.

Individuals received and reviewed the informed consent in person and, once consented, were referred to as participants. The in-person focus groups were scheduled at various outpatient and inpatient rehabilitation sites, as well as at the partnered university, where the participants first completed a demographic intake form before the focus group began. Focus groups were divided into clinician groups and into client and care partner groups to direct questions about their identified needs. Focus group sessions lasted approximately one hour and followed a semi-structured guide informed by the HAAT model (see Appendix A). The questions were structured to avoid leading participants to pre-defined answers. Open-ended questions and prompts were employed, ensuring that discussions flowed naturally rather than following predetermined lines of thought. The focus group moderators were licensed clinicians with a background in 3D printing knowledge as an occupational therapist, physical therapist, or speech-language pathologist. During the session, a member of the research team took handwritten field notes, while another member provided general technical support for recording the focus groups.

2.3. Data Analysis

All focus groups and interviews were recorded and auto transcribed through the Zoom recording platform (<https://www.zoom.com>, accessed on 20 September 2024), then manually cleaned for accuracy. Data were analyzed using Braun and Clarke's six-step reflexive thematic analysis [18]. Analysis was conducted through a sequential, iterative, hand-coding process by the third through fifth authors, who were research team members. The HAAT model served as a sensitizing framework to guide attention to the interaction among the person, activity, AT, and context; however, coding remained open to meanings generated from the data. The initial open codes were developed by breaking the transcripts into smaller units of meaning. Each transcript was first coded by one research team member. In the next stage, a second research member individually reviewed the coded transcript, considered whether codes required modification, and further identified interpretive meaning within the transcript. The first author then reviewed the codes across transcripts to organize the categories based on similarities to form initial subthemes. A full transcript review was included in this process to ensure that relevant data were captured within the developing subthemes. Initial themes were then grouped, generated, and refined through team-based discussion. The last author reviewed the themes and provided additional revisions to ensure that the final themes accurately reflected the intended analytic meaning. To support trustworthiness and transparency, the team maintained an audit trail documenting coding decisions, theme revisions, and interpretive discussions.

2.4. Researcher Reflexivity and Positionality

The research team brought diverse personal, educational, and professional experiences to the study of 3D printing in rehabilitation and healthcare. The team included rehabilitation faculty and occupational therapy graduate students with interests in assistive technology, accessibility, and the use of emerging technologies to support participation. Several team members approached the study with prior awareness of the potential for 3D printing to improve access to customized assistive technology, while also recognizing that barriers such as cost, knowledge, availability, stigma, and unequal access may limit its usefulness or acceptability for some individuals and communities.

As part of the reflexive process, the team developed individual positionality statements and a shared team positionality statement before and during analysis. These statements acknowledged the personal and professional experiences that shaped the team's perspectives, including experiences related to disability stigma, underserved communities, clinical rehabilitation, caregiving roles, technology access, and advocacy. The team also recognized that enthusiasm for 3D printing and rehabilitation technology could influence interpretation of the data. To address this, reflexive discussions were used to identify assumptions about the value of 3D printing, consider how clinical and educational perspectives may shape interpretation, be attentive to both positive and negative participant experiences, and remain open to perspectives from participants who may experience barriers to 3D printing or do not perceive it as their preferred solution. This process supported transparency in coding, theme development, and interpretation of findings. The team also maintained an audit trail documenting coding decisions, theme revisions, and interpretive discussions.

3. Results

Eighteen (18) individuals participated in four focus groups and one semi-structured interview. The four in-person focus groups included 17 participants: Focus Group 1 included clients who use AT; Focus Groups 2 and 3 included rehabilitation clinicians; and Focus Group 4 included clients and one care partner. One additional semi-structured interview was conducted with a care partner. The fifth session was originally planned as a care partner focus group; however, because only one care partner could attend due to scheduling challenges, the session was conducted as an individual, semi-structured interview using the same discussion guide.

Participant demographics are outlined in Table 1. Participants ranged in age from 27 to 80 years and were predominantly white (94.4%) and female (77.8%). Among the clients, diagnoses included spinal cord injury ($n = 1$), spina bifida ($n = 1$), brain injury ($n = 1$), cerebral palsy ($n = 1$), neurological conditions ($n = 2$), and amputation ($n = 1$). There was one parent and one spouse representing care partner roles ($n = 2$). Clinicians were represented within respective disciplines of OT, PT, and SLP.

Table 1. Participant information.

ID Code	Age	Gender	Role and Background	Examples of 3D-Printed AT Use	3D Printing Familiarity	Focus Group/Semi-Structured Interview
C1	63	Male	Client—C4 spinal cord injury	Power wheelchair joystick (custom)	Extremely familiar	FG 1
C2	47	Female	Client—Spina bifida	E-tablet holder (pre-designed)	Extremely unfamiliar	FG 1
C3	27	Female	Client—Brain injury	E-tablet holder (custom)	Neither familiar nor unfamiliar	FG 1
C4	57	Female	Client—Cerebral palsy	Phone holder (custom)	Somewhat familiar	FG 1
C5	80	Female	Client—Inclusion body myositis	Stylus (custom); Door handle opener (custom)	Somewhat unfamiliar	FG 4
C6	49	Female	Client—Multiple sclerosis	Phone holder for scooter (custom); Drink holder for scooter (custom)	Somewhat familiar	FG 4
C7	74	Male	Client—Amputation	Nail clipper holder (pre-designed)	Somewhat unfamiliar	FG 4
P1	83	Male	Care Partner—Spouse	E-tablet holder (pre-designed)	Somewhat familiar	FG 4
P2	44	Female	Care Partner—Parent	Cup holder with handles (custom for child size)	Somewhat familiar	Interview 1
R1	29	Female	Rehab Clinician—Speech language pathologist	Requested/used 3D-printed AT in clinical practice	Somewhat familiar	FG 2

Table 1. Cont.

ID Code	Age	Gender	Role and Background	Examples of 3D-Printed AT Use	3D Printing Familiarity	Focus Group/Semi-Structured Interview
R2	63	Female	Rehab Clinician—Occupational therapist	Requested/used 3D-printed AT in clinical practice	Extremely familiar	FG 2
R3	29	Female	Rehab Clinician—Physical therapist	Requested/used 3D-printed AT in clinical practice	Somewhat familiar	FG 2
R4	33	Female	Rehab Clinician—Speech language pathologist	Requested/used 3D-printed AT in clinical practice	Somewhat familiar	FG 2
R5	36	Female	Rehab Clinician—Occupational therapist	Requested/used 3D-printed AT in clinical practice	Extremely familiar	FG 2
R6	62	Female	Rehab Clinician—Physical therapy assistant	Aware of 3D-printed AT processes in the network	Extremely unfamiliar	FG 2
R7	48	Female	Rehab Clinician—Physical therapy assistant	Aware of 3D-printed AT processes in the network	Somewhat familiar	FG 2
R8	33	Female	Rehab Clinician—Physical therapist	Requested/used 3D-printed AT in clinical practice	Somewhat familiar	FG 3
R9	36	Male	Rehab Clinician—Occupational therapist	Requested/used 3D-printed AT in clinical practice	Somewhat familiar	FG 3

Note: FG = Focus Group.

Stakeholder perspectives gathered through focus groups and one semi-structured interview provided first-hand feedback and individual perceptions of AT related to 3D printing, promoting a thorough understanding of current affordances and barriers. The reflexive thematic analysis identified three key themes: (1) AT adapts to meet individual needs but encounters practical challenges; (2) 3D printing as an evolving and practical solution for enhancing access to AT; and (3) 3D printing education and support to optimize AT service delivery. Figure 1 outlines key quotes supporting the identified themes. Quote codes are categorized by roles: Client (C), Care Partner (P), and Rehabilitation Clinician (R).

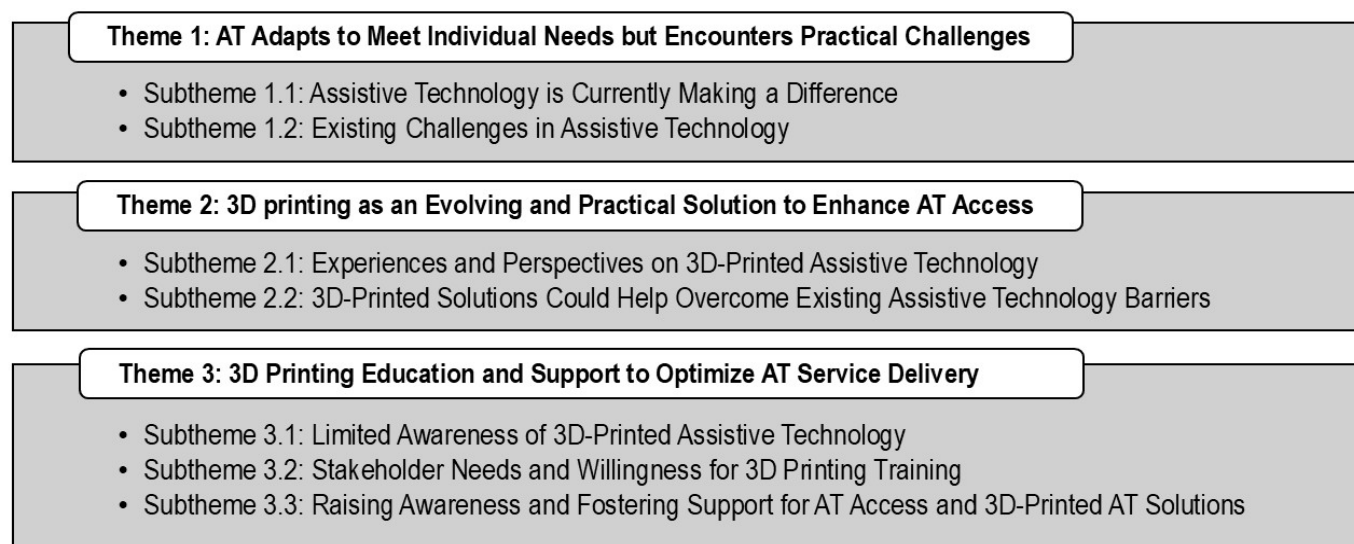


Figure 1. Themes and subthemes from the thematic analysis.

3.1. Theme 1: AT Adapts to Meet Individual Needs but Encounters Practical Challenges

Participants acknowledged that, although assistive technology (AT) provides substantial benefits and is extensively utilized across various care environments to improve the

quality of life for clients and caregivers, all three stakeholder groups recognized discernible challenges in its practical application.

3.1.1. Subtheme 1.1: Assistive Technology Is Currently Making a Difference

All stakeholders highlighted that AT is vital for enhancing independence, safety, empowerment, and overall quality of life for individuals with disabilities and their care partners. R5, a rehabilitation clinician, explained that it helps users carry out daily tasks more easily, offering a *“level of independence for patients who might not previously have a shot at it,”* and thereby promoting a sense of freedom and self-reliance. For many, AT eliminates the need to depend on others for daily tasks, reducing physical and emotional strain on care partners and fostering a sense of control over their own lives. C5, a person with a disability, shared how AT provides independence, saying, *“So once this came, I’ve been a free bird ever since, and I’m loving every moment of it.”* P1, a care partner of an adult with disability, shared the same sentiment about its benefits for him and his wife, stating, *“For a caregiver, it makes a world of difference. The more that she does, the less I have to do.”* All groups emphasized that AT solutions not only fulfill functional needs but also promote independence and well-being.

Taken together, these findings suggest that participants did not view AT as a single device or product, but as an essential part of daily participation, independence, and caregiving routines. However, participants’ experiences also demonstrated that the value of AT is shaped by the service delivery systems surrounding it, including funding, acquisition, customization, repair, and follow-up. Across stakeholder groups, participants described a gap between having access to AT and having access to a device that fits the person, activity, environment, and changing functional needs over time.

3.1.2. Subtheme 1.2: Existing Challenges in Assistive Technology

Our stakeholders also discussed numerous ongoing challenges in obtaining timely access to AT, including cost, insurance coverage, customization, and durability. The high cost of AT devices was identified by our multidisciplinary respondents as a significant barrier to acquiring commercial AT equipment. C3 emphasized this by commenting, *“they’re expensive. . . a lot of them. . . and we are not allowed to have money!”* Financial burdens associated with modifications to AT devices were also noted.

Rehabilitation Clinicians identified navigating insurance approvals and obtaining AT devices from suppliers as significant barriers. R5 described, *“I’ll have patients that have waiver funding, and they can’t get something approved until insurance denies it. But vendors will not see the patient to get the denial, because they don’t make money from it.”* R3 discussed experiencing long wait times for the delivery and repair of AT devices as a significant barrier to service delivery, *“power wheelchairs. . . sometimes it takes forever for it to get delivered. If a part is back ordered, as simple as like their seat belt. . . it takes 6 more months for the chair to be delivered, and if it’s not correct, or something breaks right after, if we don’t have replacement parts, then the person is stuck.”*

Participants also noted that customizing AT devices was challenging. C1 and C3 highlighted the difficulty due to the lack of individualized AT devices.

C1: *One design doesn’t always work for everyone.*

C3: *Yup*

C1: *Sometimes we have to change the design a little bit in order for it to be individualized.*

R5 similarly explained the challenge of achieving a proper fit, saying, *“I think one of the issues that I have had a couple of times is depending on what I’m requesting, and the person, is the customization of fit.”* Another key issue raised by various stakeholders was the lack of

durability of AT devices. R9 noted, *“Lack of durability, some of the devices, especially some of the ones that are used more often.”*

3.2. Theme 2: 3D Printing as an Evolving and Practical Solution to Enhance AT Access

3D printing is increasingly being adopted as a flexible and effective way to customize AT and quickly meet end-user requirements in a cost-efficient manner. All stakeholders shared their experiences with 3D-printed AT in practice and discussed ways it currently assists them in their daily lives, as well as how they perceive 3D printing could benefit them and those they serve.

3.2.1. Subtheme 2.1: Experiences and Perspectives on 3D-Printed Assistive Technology

Stakeholders described their current experiences with 3D-printed AT. All research participants had different levels of exposure and experience with 3D-printed AT devices. C3 discussed how the addition of a 3D-printed iPad control enhancer has augmented her ability to perform a broader range of tasks independently on her device. *“So it [3D-printed device] has 3 pegs on it, so that I can use my arm to [touch] my iPad. . . I’m able to turn, instead of having to ask someone to turn it. When I want to play my games. . . I can just turn it myself. . . I’m doing a lot more stuff on my iPad now because of it.”* R3 also shared her success with 3D printing and how it has been life-changing for her client’s powered mobility independence. *“One of our residents who has an adaptive driving aid slots onto his hand, [he] calls it the ‘knuckle buster’. He was not very successful driving with his hands before, as an incomplete C4 quad, and now he’s zipping around everywhere, and it’s amazing to see. . . where we can’t find a commercial product that works, like that is a lifesaver for us.”*

Rehabilitation clinicians also expressed satisfaction with the quality and durability of 3D-printed devices. R4 mentioned being pleased with most of the 3D-printed devices they have designed, with assistance from the 3D printing expert in their team facility, *“They’re stronger, actually, than I expected. I also liked the detail and the things you had printed for me, which was like a system. . . I didn’t think there could be that much detail, including things that are 2 inches big.”*

All participants who used 3D-printed AT discussed the important role of 3D printing rehabilitation specialists in ensuring successful access to and use of these devices. R8 noted how the opportunity to collaborate with 3D printing rehabilitation experts was crucial, saying, *“I mean, you [3D printing clinical specialist] are super collaborative, and go through the whole process and of everything, and I think it’s been great . . . I totally agree.”* Stakeholders also emphasized the importance of creativity and teamwork among rehabilitation clinicians, end users, and specialists, as critical factors in the access to and adoption of 3D-printed assistive technology. A care partner mentioned the guidance and support of their rehabilitation provider, *“The therapist helped us be able to get those things”* (P2).

3.2.2. Subtheme 2.2: 3D-Printed Solutions Could Help Overcome Existing Assistive Technology Barriers

Most participants emphasized the potential of 3D printing to advance innovation and personalization in AT, as well as to serve as a practical solution to issues associated with existing commercial AT. All three groups of interviewees reported that 3D printing offers quicker turnaround times, unique customizable options, and increased comfort and durability while improving functionality at a fraction of the cost.

Participants highlighted the ability of 3D-printed AT to address unique challenges that standard AT equipment cannot, such as adding handgrips to walkers or other adaptations to mobility devices. They frequently emphasized the potential for customization offered by 3D printing. R3 explained, *“...the customization of things. . . there’s just nothing of its kind. So it’s like the perfect fit.”* Adaptations and customizations enabled by 3D-printed devices

provide functionality for clients in their homes; as R8 stated, *“Hand grips on a walker, that’s something that the 3D printing has been awesome with to help give patients when they go home.”*

The interviewees also emphasized the flexibility and affordability of the 3D-printed devices. Participants discussed the importance of the lower cost, agreeing with the statement, *“I know making this stuff isn’t as expensive as buying the equipment”* (C3). Clinicians also emphasized that the availability of 3D printing options could streamline the process, reducing the time needed to deliver AT devices to their clients, and help overcome challenges related to service delivery, such as funding, insurance claims, and the time required to search for suitable AT devices and verify insurance coverage. R1 described this, *“I need some low-tech options for communication [devices that are] a little bit more personalized for my patient. Rather than having to do a ton of digging, what is available, and what would insurance pay for? . . . To be able to totally jump over that and just to be able to take advantage of this resource [3D printing] that we have already here.”* These considerations demonstrate the evolving potential of 3D printing to create affordable, functional adaptations that enhance the usability of AT and address unmet needs.

Across participant groups, 3D printing was described as most valuable when it addressed a specific mismatch between an individual’s needs and the limitations of existing commercial options. Participants viewed 3D printing as a problem-solving pathway that could bridge gaps in fit, access, affordability, and timeliness, rather than as a replacement for traditional AT. This was especially evident in examples where small modifications produced meaningful functional gains, suggesting that the impact of 3D-printed AT may not depend solely on the complexity of the printed device.

3.3. Theme 3: 3D Printing Education and Support to Optimize AT Service Delivery

The participants discussed in agreement of the limited awareness regarding 3D-printed AT and the need for guidance on its practical application in healthcare.

3.3.1. Subtheme 3.1: Limited Awareness of 3D-Printed Assistive Technology

All stakeholders discussed the limited awareness among users and rehabilitation clinicians of 3D printing’s capabilities, which impedes the adoption of this technology. R8 noted this lack of awareness, saying, *“I think probably education is probably the biggest thing, cause I don’t think a lot of people even know something like this.”* C1, a client, also shared this lack of awareness, emphasizing, *“I didn’t understand there was a whole world like this out there.”*

Misconceptions about the quality of 3D-printed devices, such as the perception that they are *“kind of like homemade”* (P2), may hinder a user’s acceptance of these devices and consideration of the need to continuously adapt them over the lifetime of a child with a disability. Knowledge and perception gaps around 3D printing add another layer of complexity, as those new to it may have unrealistic expectations about its limitations. R3 described, *“I think it was like everything is good with it. Um, I think if there was a stronger like material for certain things, when we’re looking at, I’m thinking about a cup holder that [Name Redacted] made, and it was great. We were trying to slot it onto someone’s, or mount it onto someone’s wheelchair, and we needed to make a mounting bracket for it. Just I think, the nature of the material that the 3D printer utilizes. It’s just, it doesn’t hold up to force on like from a nut and a bolt. So, if there was like, eventually, some type of heavy-duty material that’d be better than just like the webbing inside because it strips and cracks, and that’s the piece that’s difficult. Other than that, everything’s great.”*

3.3.2. Subtheme 3.2: Stakeholder Needs and Willingness for 3D Printing Training

All stakeholders underscored the significance of continuing education, outreach efforts, and support networks in raising awareness of 3D-printed AT options and helping individuals adopt and use these devices effectively. Additionally, clients with disabilities

and their care partners stressed the importance of education and community outreach to raise overall awareness of AT solutions.

Stakeholder participants discussed taking the initiative to seek out or create groups focused on adaptive devices to build connections with like-minded people. Social media groups emerged as a popular choice to improve awareness, such as *“a discount group on Facebook, specifically for families that have kids with disabilities or special needs”* (P2). Participants also highlighted the importance of connecting families with similar AT needs and involvement in support systems.

Rehabilitation clinicians expressed a willingness to learn more about 3D printing capabilities, indicating openness to incorporating this technology into their practice. One clinician explains, *“I didn’t have any idea of what the extensive . . . ability that we have with our 3D print [services],”* and further added, *“since then, I’ve printed a bunch of the fidget toys”* (R4). Existing educational resources were also found to be highly impactful and beneficial, as noted by one rehabilitation clinician who completed a course on 3D printing, who described it as *“super informative”* (R8). This statement highlights the positive impact of training and outreach in expanding the understanding of 3D printing’s potential.

Clients and care partners shared a profound appreciation for trial and error in 3D printing. Clients expressed increased satisfaction with the opportunities to trial multiple options before finalizing their selection. A positive attitude emerged among clients regarding the correlation between multiple trial modifications and improved device functionality and fit. There was a shared sentiment that although a printed device may take *“three tries. . .”* it would continue to improve with each trial, as expressed, *“you know, each time it got better and better”* (C1).

Clinicians also highlighted the challenges of managing productivity with limited time for training and device trials. They agree that, although helpful, training sessions should be concise and identify and train expert users in 3D printing in the departments. Clinician R8 discussed while locating and trialing devices, *“I think in general still just like time . . . you just constantly feel the grind and the crunch. . . and then I’m not charting while I’m doing all of that,”* with suggestions to run in-services to briefly train in using the printed devices and identify *“superusers”* (R8) to streamline processes.

3.3.3. Subtheme 3.3: Raising Awareness and Fostering Support for AT Access and 3D-Printed AT Solutions

It was suggested to embed 3D printing hubs within the healthcare system to ensure technology exists in practice. Providers also discussed the possibilities of a more efficient process for requesting 3D prints through accessible order forms. *“If we could have [physical] order forms in our department, just make it more present so people are aware of it”* (R5). This indicates the need to adjust how providers are made aware of and obtain prints through a more convenient ordering process.

The interviewees also emphasized the importance of providing rehabilitation clinicians, clients, and care partner teams access to and support from specialists in 3D printing across multiple point-of-care sites within the healthcare system. R1 described this support need, *“I’ve gone through the [3D-printed AT] catalog multiple times. But I, I feel like every time I’ve reached out for something. It is during a session. There’s a problem, or a situation. And then an idea happens like, I’m not able to think of ideas without the situation that calls for it. I can’t just be like ‘oh that like might really work’, or ‘we’re lacking that in rehab world’ like no, I need it to be in front of the patient.”* Clinicians were consistent in their desire for an improved delivery process, including opportunities for structured follow-up sessions focused on device functionality and user satisfaction over a period.

These findings indicate that adoption of 3D-printed AT depends on stakeholder awareness, clinician confidence, and access to design support. Participants’ comments suggest

that education alone may be insufficient if clinicians do not also have clear workflows, expert consultation pathways, and structured follow-up processes. Overall, 3D printing emerged as both an AT innovation and a service delivery innovation requiring coordinated support across clients, care partners, clinicians, and specialists.

4. Discussion

Through focus group discussions and one semi-structured interview with various stakeholders, we examined the potential of 3D printing in assistive technology (AT). Our data highlighted some clear advantages as well as the current barriers to the adoption and availability of 3D-printed AT. The current findings are consistent with prior research describing 3D printing as a promising approach for improving customization, affordability, and functional fit of AT. Previous studies have described 3D-printed writing and typing devices, mobile device access adaptations, powered mobility supports, orthoses, and other personalized assistive devices as feasible approaches when commercially available options do not fully address user needs [8–13]. Similarly, participants in the present study described 3D printing as valuable when it allowed devices to be adapted to a person's body, activity demands, equipment, or environment.

The findings also align with prior work identifying affordability as a key advantage of 3D printing. Hunzeker and Ozelie described 3D printing as a potentially cost-effective application within occupational therapy practice, while Simpson and Taliaferro highlighted the role of 3D printing in expanding participation through lower-cost, customizable supports in adapted physical education [19,20]. In the present study, participants similarly perceived 3D-printed devices as being lower-cost and faster to obtain than devices acquired through traditional procurement pathways. These findings suggest that customization and affordability are not only device-level benefits, but also service delivery considerations, particularly when insurance coverage, vendor delays, and replacement costs limit timely access to AT.

Prior literature also supports interpreting 3D printing as a complement to, rather than a replacement for, traditional AT. Studies comparing 3D-printed devices with standard devices have reported comparable performance rather than consistent superiority [14–16]. This is consistent with participants' perspectives in the current study, as they described 3D printing as valuable for individualized problem-solving while also raising concerns about durability, material strength, and the need for continued revision. These findings suggest that clinical decision-making should consider the intended activity, device complexity, material properties, and daily use demands when determining whether a 3D-printed solution is appropriate.

Participants' comments also highlight that 3D-printed AT exists along a continuum of customization complexity. Some devices, such as grips and holders, or adaptations to existing equipment, may be created or modified through straightforward design modifications. Other devices, particularly those that interface directly with the client's body, mobility equipment, or powered wheelchair controls, may require more advanced design expertise and multiple rounds of testing and revisions. Therefore, the degree of customization needed should inform the level of clinical, technical, and design support required. In addition, the quality and durability of 3D-printed components are influenced by multiple factors, including material selection, printer type, print process, print settings, geometry, post-processing, and the physical demands placed on the device during use. These considerations are important because stakeholder experiences with 3D-printed AT may differ depending on whether a device is used for light-duty tasks, repeated daily handling, or direct contact with the client's body. As 3D printing becomes more integrated into rehabilitation service delivery, clinicians and 3D printing specialists should consider both

the design complexity and the intended use environment when determining whether a 3D-printed solution is appropriate.

This present study adds to the literature by extending the investigation from device performance alone to the implementation conditions needed for 3D-printed AT to be successful in rehabilitation service delivery. Stakeholders emphasized that access to 3D printing is not sufficient without education, collaboration, structured follow-up, and access to trained personnel with design expertise. Previous concerns were similarly noted in the literature when identifying the need for training and workflow integration to support adoption [21]. The present findings further suggest that a dedicated 3D printing specialist or “makerspace” may help bridge the gap between a clinical and practical need and create a device that can be revised over time.

Our participants identified barriers to commercial AT, including challenges with device use, insufficient training, cost issues, and limited ongoing support [22]. The World Health Organization (WHO) further highlights issues such as lack of awareness, unaffordable prices, limited access, and substandard product quality and variety [1]. Together, these challenges often hinder effective AT implementation and user satisfaction. While previous research lacks practical solutions to the identified barriers and does not include detailed stakeholder perspectives, our study sought specific, personal insights from providers and end users to validate aspects of 3D printing and identify key topics.

The need for education, workflow development, and dedicated personnel identified in this study is consistent with broader international efforts to improve rehabilitation. The WHO Rehabilitation 2030 initiative emphasizes the importance of coordinated action to strengthen rehabilitation as an essential component of health systems, including the development of multidisciplinary rehabilitation workforces, improved service delivery, financing, and rehabilitation-related data and research [23]. Similarly, the WHO Rehabilitation Competency Framework describes the shared values, competencies, behaviors, knowledge, and skills needed by the rehabilitation workforce to deliver quality care across professions, settings, and service contexts [24]. Within this framework, integrating 3D printing into AT service delivery requires more than access to technology; it requires clinician education, interprofessional collaboration, specific referral and follow-up processes, and access to personnel with specialized design and fabrication expertise. These findings suggest that 3D-printed AT implementation should be considered within the broader rehabilitation workforce and service delivery planning, rather than as a technological innovation alone.

4.1. Limitations

This study has several limitations. First, the sample was small and drawn from one rehabilitation system and partnered university, which may limit transferability to other rehabilitation settings. The sample also lacked racial and gender diversity, and only two care partners participated, limiting the range of care partner perspectives represented. In addition, participants were recruited based on prior exposure to 3D printing, which may have resulted in more favorable perceptions than would be expected among individuals without prior exposure. Focus group composition and discussion flow varied across groups, and not all participants responded to every question. Finally, the specific materials, printers, and fabrication processes used for participants’ 3D-printed devices were not systematically evaluated; therefore, findings related to durability and quality should be interpreted as stakeholder perceptions rather than technical outcomes of 3D printing.

4.2. Implications for Rehabilitation Practice and Education

The findings of this study have several implications. Immediate revisions within rehabilitation settings could be implemented to improve awareness of the possibilities of

3D printing, ensure the printing process and service delivery run smoothly, and include structured follow-ups for modifications to prints. Rehabilitation providers may provide educational opportunities to improve awareness of 3D-printed AT, either directly through face-to-face collaborations or indirectly through external platforms such as social media ads or groups. This includes education from providers to end users, as well as education from the rehabilitation site itself to current and incoming staff on available technologies and 3D printing capabilities that exist within their network. Increased verbal and written education ensure that clinicians, clients, and care partners are equipped with the knowledge needed to create or utilize customized printed devices. Health care professionals should continue to value and prioritize collaboration to involve clients and care partners in the design process to improve user outcomes. Collaboration should continue beyond the physical delivery of the process and expand to include teaching or customization follow-up sessions.

A key contribution of this study is the identification of service delivery considerations necessary for the successful implementation of 3D-printed AT, including dedicated personnel, streamlined ordering processes, and structured follow-up mechanisms. By integrating these considerations into rehabilitation settings, rehabilitation stakeholders may experience improvements in the accessibility, efficiency, and responsiveness of 3D-printed AT service delivery. Integrating 3D printing into rehabilitation therapies supports a client-centered approach by addressing individual needs that traditional AT often lacks, and its versatility in modifications and customizations allows therapists to create devices that best fit clients.

Future research should focus on addressing the challenges identified by both end-users and providers and consider a prospective design with a more diverse sample. Given end-users' insights into the value of trial-and-error, further studies should explore the effectiveness of structured trial opportunities and the impact of follow-up sessions on user satisfaction and outcomes. From the provider's perspective, future research should explore integrating 3D printing into healthcare systems, including developing efficient ordering processes and improving training and follow-up programs to accommodate clinicians' time constraints. These areas of research will help refine the implementation of 3D-printed AT to promote better adoption, sustained use, and enhanced outcomes for both end-users and providers.

5. Conclusions

3D printing represents a feasible and promising approach to enhancing AT service delivery. Participants identified important benefits, including affordability, customization, rapid modification, and client-centered design. However, successful implementation requires more than access to 3D printing technology alone. Findings indicate the need for education, dedicated personnel to support iterative design processes, streamlined referral and ordering systems, and structured follow-up to support safe and effective use. Future research should examine 3D-printed AT implementation across larger and more diverse samples, evaluate user outcomes over time, and compare service delivery models that integrate 3D printing into rehabilitation practice. With appropriate service delivery supports, 3D printing may expand access to AT and improve participation and quality of life for individuals with disabilities.

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Disability Language/Terminology Positionality Statement: The authors intentionally use the term *clients* to refer to individuals receiving rehabilitation services, reflecting the clinical and service delivery context. *Client* is an inclusive and profession-specific term used across occupational therapy, physical therapy, and speech-language pathology to denote individuals receiving care, regardless of diagnosis, functional status, or disability identity. The term *client* was chosen to promote inclusivity and reflect the relational and service-based nature of assistive technology provision.

Abbreviations

The following abbreviations are used in this manuscript:

3D	Three-dimensional
HAAT	Human, activity, and assistive technology
OT	Occupational therapy
PT	Physical therapy
SLP	Speech-language pathology

Appendix A

Focus Group Discussion Guide

* Note: Responses will be video recorded. Questions will be verbally asked to the participants.

Please note that this guide only represents the main themes to be discussed with the participants and as such does not include the various prompts that may also be used (examples given for each question). Non-leading and general prompts will also be used, such as “Can you please tell me a little bit more about that?” and “What does that look like for you?”. Questions will be adjusted for the intended audience (meaning adjusted between a group of clients who use assistive devices, for care partners, and for clinicians).

General Introductory Questions

- Let’s open the discussion with the topic of assistive technology, referred to as AT. What does the AT mean to you?
 - What adaptive or assistive technology devices might you integrate in your (work/life) to help with (physical/cognitive/social) needs for (patients/yourself/your loved one)?
- Let’s continue to think broadly about AT and your experiences. What problems, if any, have you experienced with device(s)?

- What about the service delivery of device(s), think of this from the first visit in rehabilitation, to the delivery, to follow-up and refitting or additional orders, if needed.
 - What works?
 - What doesn't work?
- How satisfied are you with commercially available AT (examples might include holders for writing implements, walkers, communication tiles, kitchen aids) for daily activities?
 - Probe: Think of a device that you use frequently in your (work/life/caregiving). Think if it could be modified (e.g., size, made for a hand, personalization).
 - What modifications would you make? Or is it fine as it is?
 - Would it work better?
 - Would it be used more?

Assistive Technology Questions (AT)

- We will now discuss the purpose of our session, which focuses on 3D printing (3DP) and how 3D-printed devices are used in rehabilitation. You have been invited to this session because you've experienced 3DP in the past, and your responses are valuable. Please be as honest as possible.
- What were your initial impressions about 3DP?
 - Where have you seen 3DP before (e.g., open house, on display at therapy, course)
 - Were the samples as you would have expected?
 - Were the samples applicable to you?

Activity Questions (A)

- Please describe a specific activity in which you integrated 3DP (e.g., kitchen tool, communication tiles, dressing aid, walker skis) for (yourself/a patient/a loved one).
- When we say the word "context," we might mean the environment in which the device was used or social or cultural acceptance. We'd like to explore this topic.
 - In what contexts is 3DP useful for the specific activity? (e.g., work culture, rehabilitation or home environments, social or cultural influences)
 - In what contexts is 3DP limited for the specific activity? (e.g., work culture, rehabilitation or home environments, social or cultural influences)
- Do you have further ideas could 3DP devices contribute to engagement in activities?
 - How so?
 - What activities?

Human Questions (H)

- 3DP may offer possible solutions. What are some challenges related to (physical/mental/social) health and independence that you think 3DP could help with as AT?
 - How?
 - Why?
- 3DP may have limitations, it is not a solution for everything. What are some challenges related to (physical/mental/social) health and independence when 3DP is not appropriate as AT?
 - How?
 - Why?

Future of Service Delivery in the lens of HAAT

- Considering our discussion before on contexts (insert specific contexts discussed), how can the service delivery of 3DP be achieved to address health challenges?
- How do you foresee 3DP devices improving overall (physical/mental/social) health?
- What opportunities do you see with regard to using a 3DP device?
 - In the short term?
 - In the long term?
- What challenges do you see with regard to using a 3DP device?
 - In the short term?
 - In the long term?
- Any risks that you associate with the use of a 3DP device?
- What barriers do you perceive in regard to accessing services?
 - Financial barriers?
 - Transportation barriers?
 - Time restraints?
 - How may 3DP ease this burden?
 - How may 3DP service delivery be improved to address the burdens?

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