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A Cost-Effective Analysis of 3D Printing Applications in Occupational Therapy Practice

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A Cost-Effective Analysis of 3D Printing Applications in Occupational Therapy Practice

Abstract

Background: Emerging research supports 3D printing can provide customizable, low-cost, and replicable items for application in occupational therapy, but more research is necessary to inform occupational therapists on why and how 3D printing would be applicable and feasible in practice.

Method: This study is a cost-effective analysis aimed to identify practical considerations of a selection of 3D printed items in comparison to commercially available items. Ten items of adaptive equipment were downloaded from open-sourced 3D printing design websites and printed. The estimated cost of material was calculated and each print time was recorded. Items with comparable design and function were selected from a thorough internet search for analysis and comparison to the 3D printed items.

Results: The results demonstrate that each 3D printed item had a positive benefit in terms of material cost and print time compared to the cost and shipping time of each comparable item.

Conclusion: The 3D printed items were the more cost-effective for all items, but most significantly for niche designs with fewer available commercial alternatives. 3D printing successfully replicated commonly used adaptive equipment for a comparable cost, while allowing for customization and the ability to provide the item in-house to clients.

Comments

The authors report no potential conflicts of interest.

Keywords

adaptive equipment, assistive device, technology

Cover Page Footnote

The authors thank the Rush University Occupational Therapy Department for funding the 3D printing materials necessary for this study and the students of the Rush University Occupational Therapy Department for participating in the 3D printing process.

Credentials Display

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With increased availability and development of 3D printing technology, many health care professions have implemented widespread applications of 3D printing into service delivery (Ganesan et al., 2016). From anatomical models used for surgical planning to custom dental or prosthetic implants, 3D printed items in health care are distinctly beneficial in that they are customizable, replicable, and cost-effective (Dodziuk, 2016). For occupational therapy (OT), this technology could provide an innovative and low-cost method for supplying prosthetics, orthotics, or other off-the-shelf equipment, including assistive devices or adaptive equipment, to clients (Schwartz, 2018).

Despite positive outcomes, 3D printing technology is not yet widely used by occupational therapists, in part, because of a lack of knowledge on how to use the technology, the potential uses in clinical practice, its feasibility, and practical considerations, such as time and cost compared to current practices (Patterson et al., 2020). However, decreasing price points and improved user-friendly designs have increased access to and the usability of 3D printers for wider implementation in health care and OT. This study uses a category of 3D printing called fused deposition modeling (FDM), in which the nozzle of the 3D printer extrudes melted thermoplastic filament that adheres on itself in layers onto the printer's build platform (Grames, 2019). As FDM is the most commonly available and cheapest type of additive manufacturing, this would likely be the type of 3D printing used for purposes in OT. Although there is a wide price range of FDM 3D printers reaching up to $10,000, desktop FDM 3D printers have become increasingly available for consumers starting at around $200–$300 (Grames, 2020). Increased access to 3D printing has also resulted in numerous open-source websites where users share free 3D printing design files, or stereolithography (.stl) files, that are available to download (Patterson et al., 2020). These websites enable anyone with a 3D printer the ability to print a wide range of items, eliminating the need to have extensive knowledge of design software to access and use 3D printing design files. Searches on these websites have yielded a large number of free downloadable and predesigned pieces of adaptive equipment that are commonly provided or that would be beneficial for OT clients.

Occupational therapists recommend adaptive equipment to clients to solve functional problems, but they may be limited to recommending expensive commercial items or a non-customizable object that does not address a client's distinct need (Schwartz, 2018). 3D printing technology can be used either to customize a novel object or affordably replicate a commercially available object, allowing for increased access to expensive adaptive equipment and assistive devices for low-resource clinics, low-income clients, and clinics in rural locations (Schwartz, 2018). 3D printing could also allow for novel innovation of an object that will better meet a client's need compared to commercial alternatives.

Demonstrating the benefit of customized 3D printed assistive devices compared to off-the-shelf items, individuals from the department of occupational therapy and the department of physical and rehabilitation medicine in Korea designed and manufactured a patient-specific 3D printed assistive device for an individual with right-sided hemiparesis (Lee et al., 2019). A custom, hand-based orthosis with a detachable connector to fix objects to the orthosis and a detachable ring to hold a pen for writing was 3D printed and evaluated. The patient's scores on the Jebsen-Taylor Hand Function Test improved significantly 1 month after application of the 3D printed orthosis and adaptations. The 3D printed assistive device also showed better results than alternative off-the-shelf assistive devices on most items of the Quality of Upper Extremity Skills Test (QUEST), including typing speed, writing, fitness to hand, and the ease of use (Lee et al., 2019). This study identifies that 3D printing enabled the authors to manufacture a low-cost, custom device that optimized the client's function better than other commercially available options (Lee et al., 2019).

In addition to providing customized items, a study by Matthews-Brownell and Hall (2018) demonstrated 3D printing's benefit of replicability. The authors investigated outcomes of 3D printed orthoses for three veterans with various chronic neurological and arthritic hand conditions. The authors scanned custom thermoplastic orthotics made by certified hand therapists, uploaded the scans as 3D design files, and 3D printed replicas of the thermoplastic orthotics. The 3D printed orthotics effectively positioned the participants' hands to the desired functional position. The authors discuss that this is the first available method to quickly duplicate a custom fabricated orthotic. The ability to cost-effectively replicate custom orthotics using 3D printing significantly increases access to care and reduces the impact of geographical barriers for clients in rural areas in a way that has never been possible before (Matthews-Brownell & Hall, 2018).

A study by Schwartz et al. (2018) aimed to develop a standardized 3D printing assistive technology intervention and research methodology for use in OT practice. The study investigated outcomes of 3D printed custom pillboxes compared to off-the-shelf pillboxes. The participants who received 3D printed assistive devices had significantly higher outcomes on standardized measures of both satisfaction and medication adherence (Schwartz et al., 2018). These outcomes support the increased feasibility of 3D printing in practice, noting that the replicable process would benefit practitioners in providing assistive technology to clients. However, the study also noted that the authors experienced several technical issues and cited the importance of future studies to report pragmatic data, such as the tools used to print, the print time, and any technological errors that were encountered (Schwartz et al., 2018).

Increased accessibility and emerging research support the benefits of 3D printed adaptive equipment in OT practice, including the customization of client-centered items and cost-effective replication of commercially available items (Lee et al., 2019; Matthews-Brownell & Hall, 2018; Schwartz et al., 2018). However, more research is necessary to inform occupational therapists on practical considerations, such as feasibility, cost, tools used, and errors experienced during the 3D printing process (Patterson et al., 2020; Schwartz et al., 2018).

Investigation of 3D printing applications in OT is critical to inform practice guidelines on this innovative technology that could transform the way occupational therapists recommend and provide items, such as prosthetics, orthotics, or adaptive equipment. As 3D printers are becoming more readily available throughout health care settings, it is the ethical responsibility of individual occupational therapists and the entire profession of OT to remain informed on the risks, benefits, and evidence of novel interventions to uphold the standards of beneficence and nonmaleficence for clients of OT (American Occupational Therapy Association [AOTA], 2015). Therefore, the current study is a cost-effective analysis aiming to identify practical considerations of a selection of 3D printed items in comparison to commercially-available alternative items. This study focused only on 3D printed adaptive equipment to address the current gap in the OT literature. The results are used to inform a discussion of feasibility, benefits, and limitations to implementing 3D printing technology in OT practice.

Method

Design

This study is a cost-effective analysis comparing the costs and print time of 3D printed adaptive equipment to the price and shipping time of obtaining commercially-available alternative items. This study did not require approval of the institutional review board.

Procedure

Ten 3D printed items were selected from free, open-sourced 3D printing design websites. Items were selected based on applicability to the domains of the *Occupational Therapy Practice Framework* (AOTA, 2014). No modifications were made to the design of any item. The items were downloaded and 3D printed. The estimated cost of material and print time was calculated and compared to the price and ship time of a comparable commercially available piece of adaptive equipment.

Materials

The Flash Forge Finder, $349, and the Flash Forge Adventurer 3, $449, were the 3D printers used for this analysis (FlashForge 3D Printer, 2018c). These are both FDM printers that take polylactic acid (PLA) filament. PLA is a biodegradable thermoplastic made from cornstarch, commonly used for FDM printing as it is durable, low-cost, and available in many colors (Simplify3D, 2020). The 3D printing filament used for each item was the Flash Forge 3D Printing Filament: 1.75 mm PLA 0.5 kg (FlashForge 3D Printer, 2018b). Both printers use the free 3D printing slicing software associated with the Flash Forge company, Flash Print, to prepare the downloaded design files prior to printing (FlashForge 3D Printer, 2018a).

3D Printing Procedure

Each 3D printed item was predesigned and obtained from open-source 3D printing design websites. The websites included Thingiverse.com and Myminifactory.com (Makerbot Thingiverse, 2020; MyMiniFactory, 2020a). Designers on Thingiverse.com used a Creative Commons license, Attribution-NonCommercial-Sharealike 4.0 International (CC-BY-NC-SA 4.0), a copyright license that enables free distribution of using, sharing, and building designs that other authors have already created with proper attribution for non-commercial or profit purposes (Creative Commons, n.d.). The designers on MyMiniFactory.com use the MyMiniFactory-Credit-Remix-Noncommercial license, which also specifies the right to use, alter, and share the design with proper attribution to the designer (MyMiniFactory, 2020b).

3D printed items were selected from an open-source website and downloaded in the form of a .stl file. The file was uploaded to the slicing software, Flash Print (FlashForge 3D Printer, 2018a). Print settings for each item were left on the default settings unless otherwise specified by the designer of the item. The slicing software estimates expected print time and estimates the amount of printing material necessary. The prepared files were saved as a geometry expressions document (.gx) file to be read by the 3D printers. The files were uploaded to the printers using a flash drive to complete each print.

Data Analysis

Cost

Each item was printed using Flash Forge 3D Printing Filament: 1.75 mm PLA 0.5 kg. Each roll of filament cost $34 (FlashForge 3D Printer, 2018b). The following formula was used to calculate the estimated maximum length of material each roll of PLA filament is capable of printing: length = mass / [density x Pi x (diameter / 2) ^ 2]. It was estimated that each roll of this filament can print up to 166.5 meters of material. The Flash Forge slicing software estimates the amount of materials in meters used for each 3D printed item. The estimated cost of each item was calculated using the following equation:

($ x / Estimated Material (m) = $34 / 166.5 m) (3D Hubs, 2019). The up-front cost of obtaining a 3D printer is not considered in this analysis.

Print Time

The 3D printers record data on both the estimated print time and actual print time after the object has been completed. The actual print time for each object as recorded by the 3D printers were used for this analysis.

Comparison to Commercially Available Alternatives

A thorough internet search was conducted to identify comparable commercially-available items to each 3D printed item. The internet sites included, but were not limited to, Amazon.com, Funandfunction.com, Rehabmart.com, Walgreens.com, Caregiverproducts.com, Tadact.com, and Arthritissupplies.com. Items chosen from the internet search were based on closest function and design to the 3D printed item. The price and anticipated shipping time were recorded of the chosen items.

Calculation of Cost-Effectiveness

The following equation was used to calculate the cost-effectiveness of the 3D printed items: Cost of Option 1 / Effectiveness of Option 1 = Cost of Option 2 / Effectiveness of Option 2 (Kaplan, 2014). This study operates under the assumption the effectiveness of both options is equivalent, as measuring effectiveness is outside the scope of this study. The result of the equation calculates how many times more cost-effective 3D printing (Option 1) is compared to the commercially alternative item (Option 2), identifying how many 3D printed items could be printed for the cost of purchasing one commercially available alternative.

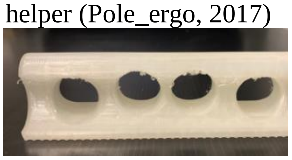
Results

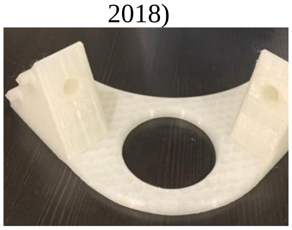
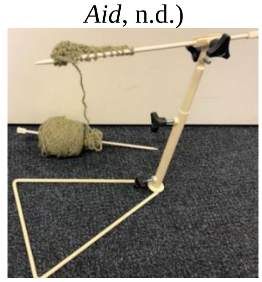
Ten pieces of adaptive equipment were 3D printed. Each 3D printed item had a lower material cost and print time compared to the price and shipping time of its selected commercial alternative. The material cost of the 3D printed items had a range of $5.54, with the lowest cost of $0.12 for a reading and writing guide strip and the highest cost of $6.04 for a foldable dressing stick. The average material cost for a 3D printed piece of adaptive equipment was $3.37. The print time of the 3D printed items had a range of 8 hr, 18 min, with the shortened print time being 10 min for a reading and writing guide strip and 8 hr, 28 min for a foldable dressing stick. The average print time of the items was 4 hr, 11 min. On average, the 3D printed items were 10.5 times more cost effective than the commercially available alternative items. Images of the completed 3D printed items, the cost of material, the print time, and comparisons to alternative options are presented in Table 1.

Table 1

3D Printed Adaptive Equipment

Data for 3D Printed Items				**Data for Commercially Available Alternative Items**		
3D Printed Item	**Material Cost**	**Print Time**	**Cost-Effectiveness**	**Commercial Alternative**	**Price**	**Shipping Time**
Bra Threading aid (Pole_ergo, 2018) 	$1.54	1 hr, 47 min	16.22x more cost-effective	(*Buckingham Healthcare Bra Angel Dressing Aid*, n.d.) 	$24.99	4–7 days

Data for 3D Printed Items				Data for Commercially Available Alternative Items		
3D Printed Item	**Material Cost**	**Print Time**	**Cost-Effectiveness**	**Commercial Alternative**	**Price**	**Shipping Time**
Push scissors (Hayashi, 2018b) 	$1.66	1 hr, 42 min	8.42x more cost-effective	(*Push Down Table Top Scissors*, n.d.) 	$13.99	4–7 days
The next beverage holder for people with disabilities (Nils, 2018) 	$5.87	7 hr, 10 min	6.80x more cost-effective	(*Bedside Beverage Holder*, n.d.) 	$39.95	1–2 days
Read and Write Guide (Hayashi, 2018) 	$0.12	10 min	38.25x more cost-effective	*(Ashley Productions ASH10802 Reading Guide Strip 1.5'' Wide, 8.5'' Length, 0.05'' Height, Clear, n.d.)* 	$4.59	1–2 days
Bottle Opener (Ivan, 2017) 	$1.56	2 hr	3.80x more cost-effective	(*Jar Opener Can Opener Bottle Opener for Seniors, Arthritis Hands and Anyone with Low Strength*, n.d.) 	$5.99	1–2 days
Modular Glass Handle helper (Pole_ergo, 2017) 	$4.18	6 hr, 33 min	7.17x more cost-effective	(*EazyHold Sippy Cup/Baby Bottle Holder, Eating Aids for Special Needs-Universal Cuff-Cell Phone-Stainless Steel Sippy-Adaptive Utensil and Drinking Aid*, n.d.) 	$29.99	1–2 days

Data for 3D Printed Items				Data for Commercially Available Alternative Items		
3D Printed Item	**Material Cost**	**Print Time**	**Cost-Effectiveness**	**Commercial Alternative**	**Price**	**Shipping Time**
Medication bottle opener (Sauer, 2015) 	$1.70	2 hr, 2 min	4.11x more cost-effective	*(Jokari Easy Open Prescription Medicine Bottle Opener and Built in Magnifying Glass. Helps Read Medical Pharmacy Label Print to Ensure Taking Correct Pills and Dosage. Unscrews Caps Easily Too, n.d.)* 	$6.99	1–2 days
Hand Grip Strengthener-Occupational Therapy (HHP_UNCC, 2019) 	$5.40	5 hr, 50 min	1.11x more cost-effective	*(Hand Grip Strengthener-Eoney Adjustable Hand Grip Exerciser, Hand Gripper with Resistance Range 22 to 88 lbs (10-40kg,* n.d.) 	$6.00	1–2 days
Foldable dressing stick (Laster, 2015) 	$6.04	8 hr, 28 min 2,510	1.3x more cost-effective	*(Luxet New Version 2 in 1 Heavy Duty 33" Foldable Shoe Horn Long Handle and Dressing Stick Sock Tool Aid Made with A Strong Steel Bar, Multipurpose, Great for Elderly Seniors, People with Disabilities,* n.d.) 	$7.95	1–2 days
Knitting aid (Pole_ergo, 2018) 	$5.63	6 hr, 8 min	17.76x more cost-effective	(*One Handed Knitting Aid*, n.d.) 	$100	3–5 days

Discussion

Cost

The material cost of all the 3D printed items was lower than the price of all of the comparable commercial items. 3D printed items were on average 10.5 times more cost-effective than commercial alternatives, supporting the assertion of previous studies that 3D printing is a low-cost technology (Dodziuk, 2016). The two items with the smallest margin of benefit were the hand grip strengthener and the foldable dressing stick, only 1.11 and 1.3 times more cost-effective than the commercial items respectively (HHP_UNCC, 2019; Laster, 2015). This may be, in part, because of the high demand of these products. Grip strengtheners are widely used in hand therapy and rehabilitation settings and dressing sticks are a common piece of adaptive equipment recommended in many OT settings for clients with a wide range of impairments. Therefore, the internet search yielded many designs and low-priced options on the market for these items.

The material cost to 3D print these items was comparable to the commercial items. Both the hand grip strengthener and foldable dressing stick required the printing and assembly of multiple parts, increasing the amount of material required. In addition, both items must be durable in order to be functional, which requires a higher infill setting. Infill settings increases the density of the printed object, and therefore a higher infill requires more material (All3DP, 2016). Although the material cost of the 3D printed items was slightly less, these results suggest 3D printing may be merely a comparable option cost-wise when the item requires printing and assembling multiple parts, requires high durability for use, and is widely available commercially.

The greatest cost difference between the 3D printed items and the comparable items was observed for the 3D printed knitting aid (Pole_ergo, 2018b). The 3D printed item was designed to hold and stabilize knitting needles to enable an individual with limitations in one upper extremity to participate in knitting. Not only did a thorough internet search yield only one item that is designed to comparably stabilize knitting needles, the item was 17.76 times greater than the material cost of one 3D printed knitting aid. As knitting is a leisure activity, this type of product may have less demand than other pieces of adaptive equipment selected for other occupations, such as activities of daily living. Under the assumption that a niche product may have fewer available options and a higher price, it can be concluded that 3D printing is especially beneficial for products that are niche in its purpose or target population for both cost and customizability for a specific condition or treatment goal (Schwartz, 2018). As a profession that distinctly addresses the occupation of leisure in our scope of practice, 3D printing could significantly increase the ability of our profession to provide client-centered products that are lacking commercially (AOTA, 2014). Other predesigned leisure items relevant to the goals of OT found on a search of Thingiverse.com include book holders, card holders, and switches for electronics and toys (Makerbot Thingiverse, 2020).

Similar observations of items with significant price differences and few comparable alternative options were observed for the bra aid and the beverage holder (Nils, 2018; Pole_ergo, 2018a). A thorough internet search yielded only one alternative: a one-handed bra threading product, which sells for 16 times higher than the 3D printed item. No similar design for the beverage holder was found, but items that function similarly to stabilize and position beverages exist at a much higher cost, almost 7 times greater for the selected item. This observation further supports that 3D printing offers a more significant cost benefit when used for items with less demand and fewer comparable commercial designs.

Although some cost differences were more significant than others, the low material cost for every 3D printed item supports the conclusion from previous literature that using 3D printing for adaptive equipment is both beneficial to replicate commonly available commercial items and create lesser available items to address a distinct functional problem (Schwartz, 2018). 3D printing successfully replicated low-cost items, such as the bottle opener, medication bottle opener, and glass handle helper, which all had numerous similar designs available on the market (Ivan, 2017; Pole_ergo, 2017; Sauer, 2015). However, these results support that 3D printing most significantly enables innovation and creativity of novel, expensive, or less commonly available items. Although numerous open-source websites already have countless available designs of 3D printed adaptive equipment, an organization called Makers Making Change further increases the feasibility of providing this service to clients (Makers Making Change, 2020). This non-profit, web-based organization allows individuals with disabilities or health care practitioners either to report a functional problem or request a novel item. A network of individuals skilled at 3D design may then volunteer to take the case and create a downloadable 3D design for the item requested or address the reported problem (Makers Making Change, 2020). The vast options allowed by 3D design and the high availability of existent downloadable 3D designs opens a world of possibilities for health care professionals interested in using this technology.

Time

The printing time for every 3D printed item was less than the anticipated shipping time for every alternative commercial item. The printing time is impacted by a variety of factors, including the size of the item, the number of parts of the item, and the infill and durability required of the item (Kondo, 2019). The shortest print times were observed in the reading strip, which took only 10 min. The low print time directly correlates with a low cost of material, which was only $0.12. This result indicates that 3D printing is significantly feasible and beneficial for both material cost and time for small items with low durability requirements.

Regardless of the wide range of print times observed, it is noted that 3D printing was beneficial in that the individual does not need to monitor or be present for the entire printing time. Each print was started and observed for 5 min to ensure successful initiation and was then left unmonitored to complete printing. This experience supports the feasibility of using 3D printing during clinical practice and supports the benefit of 3D printing regardless of the range of print times. An occupational therapist could have the item printing in preparation for a treatment session using the estimated print time, enabling them to provide a completed 3D printed item to clients in-house. This differs from other practices of recommending items and providing information on where to purchase the item, which may discourage clients with low-income or who are less compliant to follow through on the recommendation or order an item independently.

Customizability

Another key benefit observed in the 3D printing process is the ability to alter and customize a predesigned item. 3D printing slicing software allows for the adjustment of the scale or uniform measurements of an uploaded design. Further, 3D design files can be uploaded onto free computer aided design (CAD) software available online, such as Tinkercad.com (Masshambanhaka, 2019; Tinkercad, 2020). Rather than designing an object from scratch, CAD software allows the user to make slight alterations to a design or its measurements without need for extensive knowledge of design software. For example, the design file for the foldable dressing stick could be uploaded to quickly alter the length of the dressing stick to the desired measurement for a particular client. This user-friendly ability to customize an item supports that customizability is a distinct benefit of 3D printing technology compared to purchasing commercial products (Dodziuk, 2016).

The ease customization and ability to locate various online design options further enables client-centered practice by impacting the portability of use of the 3D printed items. The clinician can choose an easily portable design, such as the foldable dressing stick, or alter the measurements of the object to increase portability of the item to be used in various contexts based on each client's need. Increased customizability of 3D printed items also increases the flexibility of use, or the extent the items can accommodate a wide range of abilities, compared to commercial items (Burgstahler & Cory, 2010). The ability to easily alter the size and dimensions of the item prior to printing could allow an object, such as the medication bottle opener or bottle opener, to be used for various sized household items based on the identified need of each client (Ivan, 2017; Sauer, 2015).

Challenges and Considerations

The author of the current study experienced minimal challenges and errors in the 3D printing process for the 10 items printed for this study. One challenge identified was the maximum build volume of the 3D printer used (150 x 150 x 150 mm) (FlashForge 3D Printers, 2018c). Multiple objects including the hand grip strengthener and beverage holder had to be scaled down from the intended size to fit the build volume of the printer, possibly impacting the function of the items. Clinicians must consider the size limitation when purchasing desktop 3D printers and planning what items can be provided to clients.

The majority of the 3D printed items printed successfully without quality or technological error on the first attempt by using the default print settings unless otherwise directed by the item's designer. The modular glass handle helper is the only item that required multiple attempts and manual adjustment of print settings to troubleshoot the quality of the print (Pole_ergo, 2017). The complex shape of the item with multiple areas that overhang gravity required the addition of support material to support the bridges during printing that is later removed (All3DP, 2016). However, the flimsy support material was not adequate enough to support the bridging during the print and required experimentation with print settings, such as temperature, infill, and orientation. Although the print was ultimately successful, this provides an example that the 3D printing process may become complicated by errors and require increased time, especially for items with complex shapes. Clinicians need to be aware of the possibility of error when considering time required. Clinicians should also be educated on the purpose of basic 3D print settings to anticipate error effectively and troubleshoot during the printing process as necessary.

Limitations and Future Direction

The material cost of the 3D printed items in the current study did not reflect the upfront cost of purchasing the 3D printer or its materials. Similarly, the price of the commercially available items did not reflect shipping cost, as this cost varies with the type of shipping chosen and the location. Future studies should consider the cost of the entire 3D printing process, including the cost of the 3D printer and materials and the additional cost of shipping associated with commercial items. The results of the current study provide concrete information on the printing time and cost of each 3D printed item itself but excludes the time the author spent gaining foundational knowledge on the 3D printing process, how to use the 3D printers, and the time required to assemble some of the items after printing. Previous literature has noted the need to identify practical considerations such as time, cost, and errors in 3D printing research, as is addressed in this study, but it is also necessary to identify and consider the time involved both in learning to 3D print and in completing the item after it is printed (Schwartz et al., 2018). Future studies should consider the amount of time required of the entire 3D printing process, including learning to 3D print, ordering 3D printing materials, and assembling items, to further inform occupational therapists on the feasibility of use in clinical practice.

The current study provides results of only 10 examples of 3D printed adaptive equipment. The limited sample size provides a reference point for the cost and time spent on a selection of adaptive equipment, but the results may not be generalizable to other items depending on the size, assembly, and complexity of the item. In addition, the selected sample does not represent other applications of 3D printing in OT, including prosthetic devices and orthotics. Future studies are warranted to address other areas of 3D printing with similar methodology or expand on the selection of adaptive equipment in the current study.

The methodology did not include an evaluation of the efficacy and function of the 3D printed items. The methods for searching and identifying the most comparable commercially-available items was a nonstandardized internet search, which was susceptible to human error. Future directions in 3D printing research could include creating a standardized methodology for selecting and evaluating functional outcomes of items that could be used in OT in comparison to commercial items.

Conclusion

The results of the current study support that 3D printing is a cost-effective technology that can replicate commercially available items or customize a novel item to address a client's distinct functional problem. The results indicate that the material cost and print time of a 3D printed item is less than the price and time required to order and obtain a commercially available alternative item with a similar design and function. 3D printing was observed to be most significantly time and cost-effective for items with fewer similar commercial options available and that do not require assembly of many parts. The author's experience obtaining pre-designed items, customizing measurements, and using a desktop 3D printer supports the recommendation that occupational therapists could feasibly learn the 3D printing process with increased OT specific instructional resources and minimal training. The decreasing cost of 3D printing materials and the lack of need to monitor the 3D printer during printing maintains that this technology could be successfully integrated into clinical practice. 3D printing technology is increasingly feasible to learn, progressively more affordable to obtain, and indisputably provides innovative and low-cost items to clients. Further research on 3D printing is warranted to inform current, client-centered, cost-effective, and evidence-based service to clients of OT.

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