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Research Note

Allied Health Professionals' Views on the Use of 3D Food Printing to Improve the Mealtime Quality of Life for People With Dysphagia: Impact, Cost, Practicality, and Potential

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ABSTRACT

Purpose: Much is promised in relation to the use of three-dimensional (3D) food printing to create visually appealing texture-modified foods for people with dysphagia, but little is known of its feasibility. This study aimed to explore the perspective of allied health professionals on the feasibility of using 3D food printing to improve quality of life for people with dysphagia.
Method: Fifteen allied health professionals engaged in one of four 2-hr online focus groups to discuss 3D food printing for people with dysphagia. They discussed the need to address the visual appeal of texture-modified foods and watched a video of 3D food printing to inform their discussions on its feasibility. Focus group data were transcribed verbatim, de-identified, and analyzed using thematic content analysis. Participants verified summaries of the researchers' interpretation of the themes in the data.
Results: Participants suggested that 3D food printing could improve the mealtime experience for people with dysphagia but noted several barriers to its feasibility, including the time and effort involved in printing the food and in cleaning the printer. They were not convinced that 3D-printed food held higher visual appeal or looked enough like the "real food" it represented.
Conclusions: Allied health professionals considered that 3D food printing could benefit people with dysphagia by reducing the negative impacts of poorly presented texture-modified foods. However, they also considered that feasibility barriers could impede uptake and use of 3D food printers. Further research should consider the views of people with dysphagia and address barriers reported in this study.

The provision of texture-modified food is a common intervention in dysphagia management (Robbins et al., 2002). However, it can impact greatly on a person's mealtime-related quality of life, by disrupting the visual appeal of a meal (Keller et al., 2012; Smith et al., 2022). Ullrich et al. (2014) have previously raised the importance of visually appealing texture-modified foods for people with dysphagia, in that poorly plated food can negatively impact on food identification. Also, the pleasing appearance of food is associated with more positive flavor ratings (Ettinger et al., 2014). Several food-shaping techniques are designed to reduce the risk of unappealing food reducing the person's quality of life and improve the visual appeal of texture-modified foods (see Smith et al., in press). Techniques used to increase the visual appeal of texture-modified foods include food molds (Higashiguchi, 2013; Ullrich et al., 2014), piping bags, emulsification, spherification, gelification (Reilly et al., 2013), and three-dimensional (3D) food printing (Hemsley et al., 2019).

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However, the effectiveness of these techniques in improving the visual appeal of texture-modified foods is not well established. Furthermore, there is little research on the impact of food-shaping technologies for people with dysphagia, on either mealtime enjoyment or food intake (Smith et al., in press). Hemsley et al. (2019) noted that 3D food printers are an internet-enabled device, which may hold other benefits in the "smart home," allowing users to share food shape designs, reinforcing and capitalizing upon the "social" and community aspects of mealtimes and interest in sharing recipes and photos of food.

A recent and relatively unfamiliar technology developed for food shaping and production, 3D food printing is a form of "additive manufacturing," in that it involves a printer being used to build up or "add" layers of the food onto a flat surface so that it builds up into a 3D shape. In a 3D food printer, pureed food material (or "food ink") is pushed through a "food ink cartridge" or nozzle (much like an ink-jet printer) into layers to create a shape (Hemsley et al., 2019). The 3D food printer can be programmed to print preset or novel food shapes. 3D printing technologies were reportedly first used with food in 2007, and recent research has examined its use for creating personalized food items (i.e., to meet nutritional, textural, or flavoring needs). 3D food printing is also used commercially by some food corporations including Barilla, Hershey, and Ruffles who achieve the desired food consistency by procedures undertaken after the print (e.g., cooking the food that was printed; Pereira et al., 2021). 3D food printing technology is gaining popularity due to the taste, appearance, and texture of the food. By potentially creating foods that are texturally appropriate and visually appealing for people with dysphagia, the use of 3D food printing technologies may help to reduce food refusal and malnutrition (Hemsley et al., 2019; Pereira et al., 2021).

Emergent 3D food printing research (Hemsley et al., 2019; Raheem et al., 2021) indicates that 3D food printing could potentially bring visual appeal and customized shape to texture-modified food for people with dysphagia. However, little is known about the feasibility of 3D food printing for populations with dysphagia or their supporters, and any claims of benefit and suitability for this population are as yet largely untested (Hemsley et al., 2019). As pureed food substrates for printing can be fortified with powders (e.g., protein and vitamins), 3D-printed foods might also be used in interventions to improve nutrition. Burke-Shyne et al. (2021) explored the nutritional benefits and challenges that may arise with 3D food printing through semistructured interviews with 10 participants with a background in 3D food printing, including five dietitian–nutritionists, one allied health professional (unspecified discipline), two scientists (unspecified discipline), one social researcher (unspecified discipline), and one participant who worked for a technology company (unspecified). Participants considered that 3D food printing could be useful for people on texture-modified diets, enabling personalized nutrition, novelty food products, or nutritionally enriched foods. However, they held reservations as to the feasibility of implementation, citing technical and ethical issues related to the cost of the machine, food safety, printing speed, the stability of the printed food, the acceptability of printed food, and the level of food processing required (Burke-Shyne et al., 2021).

Given the claims of potential benefit of 3D food printers (Hemsley et al., 2019), and the findings reported by Burke-Shyne et al. (2021), which included input from dietitians, nutritionists, scientists, and technologists (but not speech pathologists or occupational therapists), it is important to broaden the field of 3D food printing research to include other allied health professionals with expertise in dysphagia management. Dysphagia management requires a multidisciplinary approach, and speech pathologists and occupational therapists, absent from Burke-Shyne et al.'s study, have an important role in dysphagia and mealtime management to improve health, quality of life, and enjoyment (Howells et al., 2019; Moloney & Walshe, 2019). Expanding the scope of 3D food printing research consultation to include these two disciplines in particular is important, so that (a) the food being designed is the correct consistency for a dysphagia diet; and (b) any additional occupational, sensory, or accessibility issues are considered in the 3D food printer design. Understanding more about potential risks and benefits of 3D food printing from the perspectives of the professionals directly involved in dysphagia management is important as 3D food printers, if effective, could be considered an assistive technology for people with dysphagia. Therefore, the aim of this research was to determine (a) the views of allied health professionals involved in dysphagia assessment and management on the feasibility of 3D food printing to increase the visual appeal of texture-modified foods, and (b) any potential impact on the participation and inclusion of people with dysphagia in designing and sharing the shape of their meals.

Method

This research was ethically approved by the University of Technology Sydney Human Research Ethics Committee. It was part of a larger doctoral research study examining dysphagia, quality of life, and 3D food printing that is reported elsewhere (Smith et al., 2022, in press).

This study followed the guidelines for reporting qualitative research using the Consolidated Criteria for Reporting Qualitative Research checklist (Tong et al., 2007). Focus groups are useful for exploring areas where little is known and for generating new ideas (Patton, 2002), which could be useful for this relatively new technology.

The collective nature of views and experiences gained through focus groups allows for further understanding of the topic of interest from the perspective of participants (Morgan, 2019). Online focus groups allowed participants from a range of geographical locations to participate in a COVID-19 safe way while COVID-19 social distancing and travel restrictions were in place (Turbitt & Jacobs, 2021).

Participants

Participants with at least 2 years' experience of working with people with dysphagia were recruited purposefully through social media and researcher networks. Snowballing recruitment was also used as participants passed on recruitment information to others. The participants were aware of the researcher's background as a female speech-language pathologist and PhD candidate prior to providing consent. In total, 15 allied health professionals (comprising 12 speech-language pathologists and three occupational therapists) took part in four focus groups. Participants were assigned to one of the focus groups based on the date and time most convenient to them. The number of participants in each group ranged from two (Focus Group 4) to five (Focus Group 1). Participants all described having had experience providing texture-modified diets for people with dysphagia, applying the classifications of the International Dysphagia Diet Standardisation Initiative (IDDSI), and considering and advising on the shaping or serving of foods for people with dysphagia.

As recruitment materials were distributed through social media, the response rate for people taking part could not be calculated. Three other speech-language pathologists expressed an interest in the research but did not respond to e-mail communication to participate in the study and were not included. Recruitment information welcomed any discipline in allied health, along with group home managers, but no other disciplines responded (e.g., dietitians, nutritionists, and physiotherapists). The four focus groups enabled researchers to gather sufficient data in terms of development of content themes through inductive analysis (Hennink et al., 2019). Table 1 provides further information on participants including their discipline, client groups seen, and the service type in which they were employed.

Procedure

Participants who provided written consent and informed the authors of their preferred date for focus group engagement were sent a Zoom link (Zoom Video Communications Inc, 2011) to attend the online focus group. All participants engaged in one of four 2-hr focus groups held from March to May in 2021. All focus groups were moderated by the first author who was experienced in qualitative research data collection and analysis and also had used a 3D food printer. Two of the focus groups were co-moderated by the second and third authors who are speech-language pathologists with experience conducting focus group research and in use of the 3D food printer. The topic guide for the focus groups was developed based on prior research (Smith et al., 2022, in press). Due to the novel nature of 3D food printing, the focus group procedure included showing participants pictures and video footage of the 3D food printing process, using a Foodini 3D Food Printer (Natural Machines, 2019; see Appendix for the topic guide and example pictures shown in the focus group). The foods used in the 3D food printing video met the texture requirements of Level 4 (Pureed) according to the International Dysphagia Diet Standardisation Initiative

Table 1. Participant information.

Participant ID label	Age	Gender	Profession	Years working with people with dysphagia	Service type	Client group
FG1OT1	18–30	F	OT	5–9	Private	Disability
FG1OT2	18–30	F	OT	5–9	NGO	Disability
FG3OT3	31–45	F	OT	10–14	NGO	Disability
FG4SLP2	18–30	F	SLP	1–4	Private, university	Disability
FG1SLP3	31–45	F	SLP	10–14	Private	Medical
FG2SLP4	18–30	F	SLP	5–9	Private, NGO	Disability, medical – rehabilitation
FG3SLP5	31–45	F	SLP	15–19	Private, university	Medical – acute and outpatient
FG2SLP6	18–30	M	SLP	1–4	Public	Medical – acute
FG4SLP7	18–30	F	SLP	5–9	Public, university	Medical – acute and outpatient
FG2SLP9	18–30	F	SLP	5–9	NGO	Disability
FG3SLP10	31–45	F	SLP	1–4	Private	Disability, aged care
FG1SLP11	18–30	F	SLP	5–9	NGO	Disability, aged care
FG1SLP12	18–30	F	SLP	1–4	Public	Medical – acute
FG3SLP13	31–45	F	SLP	15–19	Public	Medical – rehabilitation
FG2SLP15	18–30	M	SLP	5–9	Private	Disability, medical – rehabilitation

Note. ID = identification; FG = focus group; OT = occupational therapist; F = female; SLP = speech-language pathologist; NGO = nongovernment organization; M = male.

(Cichero et al., 2017) with no food additives used in the printing process (e.g., gels). During the focus group, the moderator took notes and afterward made field notes for discussion with the research team (Morgan, 2019). A constant comparison analysis was conducted across the focus groups.

The focus groups were transcribed and de-identified by the first author and imported into NVivo (QSR International, 2018) for storage and retrieval of the data, as well as thematic content analysis, which involved open and matrix coding to derive the content themes (Braun et al., 2021). All participant statements were read and re-read to determine the consistency of their comments throughout the discussion (Krueger & Casey, 2002). Discussion in focus groups can generate new ideas and lead to a change of mind. However, participants' views were internally consistent; that is, their views did not change over the course of the discussion. The researchers met several times after reading and re-reading the transcripts to discuss a wide range of open codes and agree on categories of the codes that reflected the meaning in the transcripts (Morgan et al., 1998). These iterative analyses and discussions as a research team were used to increase rigor, credibility, and trustworthiness in the analysis and reduce researcher bias (Morgan et al., 1998). Content and meaning saturation was achieved with iterative and constant comparative analysis, as no new codes were developed nor were there any new nuances within the codes once all data had been thoroughly examined by the researchers (Hennink et al., 2019). Focus groups were not reconvened to further discuss or verify the researchers' interpretations. Therefore, in order to verify the researchers' interpretations, a written summary of each focus group's content themes was e-mailed to each group's participants. Participants were invited to add, change, or remove information that they considered did not reflect their group's discussion. Ultimately, one participant from each group replied to this invitation and confirmed that the written summary reflected the group's discussions. In this research note, quotes and excerpts from the focus groups are used to illustrate the findings and increase the plausibility of the results. In the results, participants are referred to with a code reflecting focus group number and discipline. For example, Speech-Language Pathologist 3 in Focus Group 1 is identified as FG1SLP3.

Results

Experience in Food Shaping: Current Practice

Across the focus groups, participants commonly used derogatory terms to describe texture-modified foods, using descriptors such as "pureed goo" (FG3SLP5) and an "orangey brown puree in a plastic bowl" (FG4SLP2). However, participants also described trialing food-shaping strategies to improve the appearance of pureed foods and avoid a negative mealtime experience for the person with dysphagia. They described having variable experiences in using food molds, piping bags, and presenting the client a photo of the original unmodified meal beside the pureed meal. FG1SLP12 described positive outcomes (in terms of improving the appearance of pureed foods) of using food molds in a hospital setting, where foods had been shaped to look like the original food product (e.g., pureed carrot in the shape of a carrot). However, FG1SLP3 reported a negative experience with food molds, relating to food safety: "we had to get rid of those moulds because they went mouldy" (FG1SLP3). FG3SLP5 had trialed a range of food-shaping strategies across diverse settings to improve the visual appeal of texture-modified meals. FG3SLP5 considered that the adoption of these strategies depended on "buy-in" within the setting, from managers to kitchen staff, due to the additional commitment of time and effort in using strategies to improve food shape. As FG3SLP5 stated, "it really does need that drive from all angles and staff buy-in otherwise it doesn't work whatsoever."

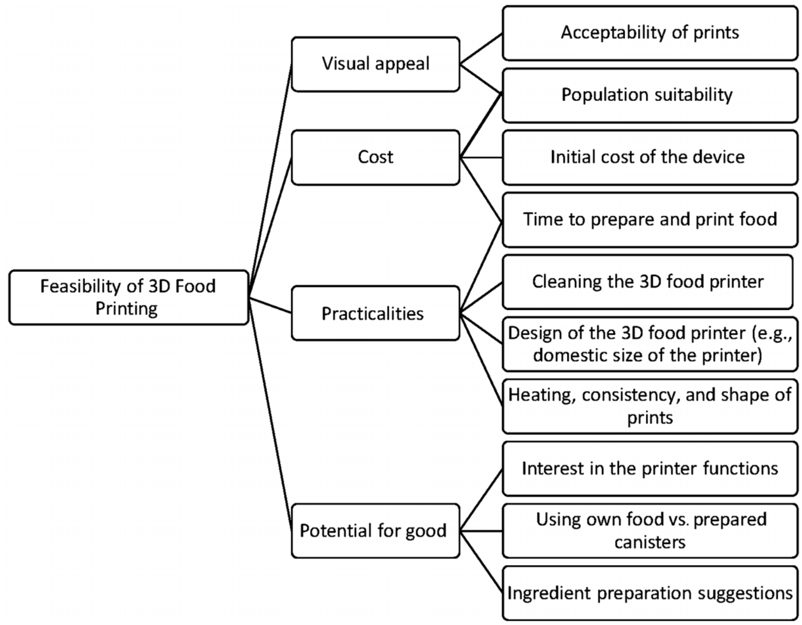
Feasibility of 3D Food Printing: Is it Worth the Effort?

There were four main content themes identified across the focus groups: (a) Visual Appeal: the impact of the visual appearance of 3D-printed food; (b) Costs: the financial and time costs involved in 3D food printing; (c) Practicality: the practicality of people with dysphagia or their supporters using the 3D food printer; and (d) Potential: the potential for 3D printing to be a "technology for good" in improving mealtime-related quality of life. Each of these themes informed and encapsulated several subcategories of meaning, which are presented in Figure 1. The distribution of coding across the focus groups is presented in Table 2.

Visual Appeal of the 3D-Printed Food

Participants in FG3 agreed on the importance of 3D-printed food looking like the original food product (e.g., a chicken leg) rather than nonfood-like shapes (e.g., gecko or flower) to create a sense of familiarity and normality. They viewed that people with dysphagia "want their food to look like their food... they just want it to look like everybody else's food" (FG3SLP5). They also suggested that printing nonfood-like shapes could be seen as "childish" (FG3SLP13) and further set the person with dysphagia apart from their fellow diners rather than support their inclusion. Furthermore, participants agreed that food shapes that do not resemble the original food may limit mealtime engagement for people with dementia or

Figure 1. Feasibility of three-dimensional (3D) food printing.



traumatic brain injury, if they are unable to recognize the food item. FG2 and FG4 participants also considered naturalistic presentation of the pureed food as being important for mealtime enjoyment. They did not consider that the 3D food printer achieved naturalistic or authentic presentation due to visible ridges on what remained a relatively flat, albeit thick 3D form. Commenting on the photo of a printed chicken leg, FG4SLP2 said "a food mould would give a more accurate representation of the chicken leg… it doesn't look that chicken-leggy." However, participants recognized that 3D food printing might allow people to be more "adventurous" (FG4SLP2) in creating shapes than they could if using the predefined shapes of food molds. Participants across FG1, FG3, and FG4 also considered that 3D-printed food may make pureed food more appealing for children, if a favorite toy or character could be printed.

Cost of the 3D Food Printer

Across focus groups, participants agreed that the 3D food printer had a relatively high financial cost of $4,000 (USD; at the time of the study) when compared with the relatively low cost of current food-shaping technologies (e.g., food molds and piping bags) and, in comparison, other kitchen appliances (e.g., food blenders and microwaves). The printing process itself was perceived to incur a cost of time that group members considered should be taken into account. The financial cost was considered a substantial barrier to the uptake of 3D food printers by people with dysphagia in hospitals, the community, or

Table 2. Distribution of coding across groups.

Three-dimensional (3D) food printing subthemes	Focus Group 1	Focus Group 2	Focus Group 3	Focus Group 4	Total number of codes in theme
Acceptability of prints	5 (20%)	0 (0%)	5 (20%)	15 (60%)	25
Population suitability	17 (50%)	5 (14.7%)	4 (11.8%)	8 (23.5%)	34
Initial cost of the device	2 (10%)	6 (30%)	9 (45%)	3 (15%)	20
Time to prepare and print food	2 (14.3%)	4 (28.6%)	5 (35.7%)	3 (21.4%)	14
Cleaning the 3D food printer	1 (5.9%)	2 (11.8%)	6 (35.3%)	8 (47.1%)	17
Design of the 3D food printer (e.g., domestic size of the printer)	0 (0%)	3 (50%)	3 (50%)	0 (0%)	6
Heating, consistency, and shape of prints	2 (20%)	2 (20%)	6 (60%)	0 (0%)	10
Interest in the printer functions	3 (17.6%)	7 (41.2%)	0 (0%)	7 (41.2%)	17
Using own food versus preprepared canisters	3 (30%)	2 (20%)	5 (50%)	0 (0%)	10
Ingredient preparation suggestions	2 (15.4%)	8 (61.5%)	0 (0%)	3 (23.1%)	13

group homes. FG2SLP6 questioned the suitability of a costly device for populations with dysphagia and suggested that many might not be able to afford a 3D food printer. In addition, funding bodies may see a costly 3D food printer as "superfluous" (FG2SLP6). This discussion reflected that cost currently was not justified by any incremental improvements in the visual appeal of the food. FG2SLP9 also stated that while access to safe food is accepted as a human right, access to visually appealing food does not have the same recognition. As a result, and considering their own views of 3D food printing, participants suggested it may be difficult for allied health professionals to advocate for the purchase of 3D food printers unless these devices could be shown to markedly improve nutrition and food intake along with mealtime enjoyment.

Practicalities of Using the 3D Food Printer

Across the groups, participants raised several perceived concerns about the usability of the 3D food printer, including the time required to prepare or print foods, clean the device, reheat the food, and ensure the suitable transportation of the food from the point of production to the table to keep its shape (see Figure 1). Participants suggested that cleaning and filling the printer capsules would be more time consuming and "not user friendly" (FG4SLP2) when compared with the time taken in other food-shaping methods (i.e., scooping food onto the plate). FG3SLP10 also commented that mealtimes at larger residential settings would continue for several hours if each meal component took 3–4 min to print. FG2SLP15 suggested that the time required to print multiple meals could be reduced if the printer was large enough to hold several plates and print multiple meals simultaneously (i.e., on an industrial scale). FG3SLP5 likened the extra cleaning requirements of the 3D food printer to the perceived inconvenience of cleaning other food processors, such as a Thermomix, exclaiming "I love my Thermomix but god I hate cleaning it." The time required to clean the small components of the 3D food printer was also seen as a barrier to its use in the community, as FG3SLP5 suggested that people with dysphagia and their family members are often time-poor owing to their increased support needs.

Participants in FG1 also discussed the logistics of printing, reheating, and transporting the food. FG1SLP3 considered that reheating 3D-printed meals may be problematic for residential settings where food temperature is closely monitored for food safety purposes. Last, participants considered the time required to transport a meal from the kitchen (e.g., in a hospital kitchen) to the person, and FG3SLP5 queried if a 3D-printed meal could maintain its shape integrity: "it might look good when it leaves [the kitchen], but does it still look like that . . . it's not leaving the kitchen and getting to the patient in five minutes."

Potential: The 3D Food Printer as a "Technology for Good"

Participants across groups agreed that improvements to the design and reduction in the cost of 3D food printers would be needed if 3D food printing was going to be a feasible option for improving the appearance of texture-modified foods and any onward benefits related to that (e.g., enjoyment, quality of life, or participation) for people with dysphagia. FG1OT1 suggested that 3D food printing could make food more exciting and give the person a sense of ownership over the food if they helped in choosing the shape and preparing or printing the food. FG1OT2 suggested the 3D food printer could be used as a therapeutic tool to engage people with the mealtime preparation process. The process could be made into a "one step" task or "multistep" task by choosing the steps the person was involved in. FG1OT2 suggested the 3D food printer could be used in social skill development groups where people could share recipes and creative food presentation ideas. FG4 participants also saw the future benefits and FG4SLP7 stated "yes there is barriers at the moment... but for that one person it could actually mean [making a difference to] their quality of life."

Participants also suggested ideas to improve the preparation of pureed food for 3D food printing. Participants in FG3 described the benefits of using customized pureed foods for printing, particularly for people with dietary requirements (e.g., allergies or gluten intolerance). For example, FG3SLP5 considered that preparing their own food for the printer could give users control over what is included in the puree, driving engagement in menu planning and purchasing of ingredients. FG3SLP5 stated "part of it is actually going to the shops and being part of a community that eats food." In contrast, FG1OT1 saw the benefits of purchasing prefilled capsules with a premade puree for the 3D food printer, as it may give people who cannot typically prepare their own meals the chance to participate, "they can get that sense of achievement and at least start being able to [participate] in that modified sense" (FG1OT1).

Discussion

In considering the potential use and benefit of 3D food printers for people with dysphagia, the speech-language pathologists and occupational therapists in this study recognized the potential benefits of 3D food printing to create more visually appealing texture modified foods. They considered these potential benefits in light of traditional food presentation methods used for texture-modified foods (e.g., scooping a spoonful of pureed food onto the plate). However, they viewed that while 3D food printing may provide another option for food shaping to improve the mealtime experience of people with dysphagia, it does not yet yield realistic or necessarily more appealing food shapes. Ullrich et al. (2014) identified that the realism of food shapes was an important factor in allowing a consumer to identify what they were eating and subsequently in the enjoyment of their meal. The novel food shapes created by the 3D printer and discussed by participants did not support food identification and therefore fell short of achieving this aim.

Furthermore, the 3D food printer was perceived as having several usability issues forming barriers to uptake and use, as well as financial and time costs, which would also need to be addressed to increase feasibility of 3D food printing in this population. These issues included the apparent complexity in skill required to fill the canisters with the food for printing and the several steps and stages involved in preparing, printing, and serving the food. People with dysphagia associated with physical or intellectual disabilities could indeed face several barriers to their use of a device, which requires use of a touch screen interface and manual filling of the printer ink cartridges. Nonetheless, participants also recognized that should 3D food printing become more usable and less costly and be improved in design, it could indeed promote a person's empowerment in designing their own food shapes and engaging in menu planning (Smith et al., in press).

The results of this research further the discussion on methods of food shaping as an important consideration for people on texture-modified diets, which include food molds and piping bags (Higashiguchi, 2013; Reilly et al., 2013). The findings support prior research on the perceived relatively low feasibility of 3D food printing for people with dysphagia (Burke-Shyne et al., 2021) and reflect mixed experiences with the use of food molds (Smith et al., in press; Lepore et al., 2014). With allied health professionals reporting barriers to food molds (including the time and difficulties with cleanliness), substantial efforts will still be needed to address the problem of the visual appeal of texture-modified foods, particularly to prevent pureed food from looking like "goo."

This study provides an in-depth understanding of the views of speech-language pathologists and occupational therapists on the feasibility of 3D food printing for people with dysphagia that reinforces and adds to the technical issues raised in Burke-Shyne et al. (2021; including print speed and cost of the printer). Prior 3D food printing research has not included speech-language pathologists or occupational therapists, and their perspectives are important, particularly in the multidisciplinary context of dysphagia management (Burke-Shyne et al., 2021; Hemsley et al., 2019). The perceived practical or usability issues are particularly important when considering 3D food printing for people with dysphagia associated with health conditions impacting mobility or cognitive skills, who would foreseeably require additional support to successfully use a 3D food printer.

Clinical Implications

This study has a range of clinical implications for the implementation of food-shaping strategies with people with dysphagia who require a texture-modified diet. The views of participants suggest that efforts should be made to shape the food so that it resembles the original food shape, for maximum benefit. Although 3D food printing may not yet be viewed as feasible, this research suggests that presenting the food in an attractive way, which is similar in shape to that of the original food product, may assist with mealtime enjoyment for people with dysphagia. The barriers to implementation outlined in this study, however, raise questions as to whether the "cost" of time and effort in attending to the visual appeal of pureed foods will help to mitigate the cost on quality of life for people with dysphagia who do not have access to visually appealing meals. Last, this study provides information on the usability of 3D food printing and barriers, which need to be overcome if it is to be implemented as a "technology for good" or assistive technology for people with dysphagia. Clinicians supporting people with dysphagia, their families, and support workers should encourage "buy-in" from all levels on the importance of food presentation, even if current techniques are limited. This may also assist in ensuring mealtime preparation is a task that the person with dysphagia is involved in as a therapeutic task.

Limitations and Directions for Further Research

This research included speech-language pathologists and occupational therapists but not dietitians or nutritionists who are also essential in the management of dysphagia in terms of meeting the person's dietary requirements. Had members of these groups been included, the ideas generated might have been expanded in relation to the claims of 3D food printers aiding nutrition and insights into adoption or usability might have been expanded. They may have also identified further opportunities for personalized nutrition for people with dysphagia as introduced by Burke-Shyne et al. (2021) and Pereira et al. (2021; e.g., diabetic or vegetarian diet). A wider multidisciplinary view may also help identify other populations that 3D food printing may be beneficial for including people with sensory food difficulties. A further limitation was the lack of opportunity for participants to see the 3D food printer being used in person. The study was conducted online by necessity owing to COVID-19 restrictions on travel and social distancing rules. Consequently, participants' views on 3D food printing were based on the information, pictures, and videos shown by the focus group moderator rather than an in-person experience in using the printer, which might have yielded additional insights as to usability and potential benefit. For example, the occupational therapists may have identified fine motor skills that needed consideration.

Future research should examine how dietitians and nutritionists, people with dysphagia, and their supporters engage with a 3D food printer and their views of the acceptability or use of these devices. Further research involving in-depth interviews with people with dysphagia and their supporters about their mealtimes and views on 3D food printing are currently being conducted. Future research with allied health professionals involved in texture modification may also allow for testing of printed food to determine if the food continued to meet IDDSI guidelines or if the flavor is compromised. The themes identified in this study could help to inform future controlled trials comparing 3D-printed foods with other food-shaping techniques (e.g., piping bags and food molds), particularly in terms of usability, perceptions of the realistic nature of the food printed, and comparing visual appeal and acceptance. A cost–consequences or cost–benefit analysis could also help to identify parameters to be considered beyond the financial cost of a 3D food printer. The findings of this research should also be seen as further impetus to drive improvements in the user-centered co-design and engineering of 3D food printers to increase feasibility for use by people with dysphagia and their supporters.

Conclusions

This study examined the views of allied health professionals, specifically speech-language pathologists and occupational therapists involved in dysphagia management, on the use of 3D food printing to improve the visual appeal of texture-modified foods for people with dysphagia. Their discussions revealed the importance of considering whether 3D food printers do actually improve the visual appeal of the food and of balancing both financial and time costs relating to the purchase and use of a 3D food printer. Several barriers were discussed, and these would be likely to impede the use of the 3D food printer as a "technology for good" to improve mealtime experiences and the acceptance of pureed food. The barriers noted in this study need to be addressed before any benefits of 3D food printing for people with dysphagia may be realized. Further research should include people with dysphagia, their supporters, and other allied health professionals to determine their views on the acceptability of 3D-printed foods in comparison to other food-shaping methods. This will ensure that a holistic view of the feasibility of 3D food printing for people with dysphagia is achieved.

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Appendix

Topic Guide for Focus Groups

1. How do you currently provide texture-modified foods? (e.g., food shaping, molds, and piping bags) and how effective are these methods?
2. Short introduction to three-dimensional (3D) food printing and a picture sequence of 3D food printing (Natural Machines, 2019).

Introduction to Foodini 3D printer: “This is the Foodini 3D food printer which prints food in the form of puree or paste. The puree is put into capsules and then pushed out to make the food item (similar to an inkjet printer). Once the food is printed, it can be eaten as is, cooked or frozen to be reheated at a later time.” Participants are shown a video and eight photos of the 3D food printer and printed foods (see example photos of 3D-printed food).

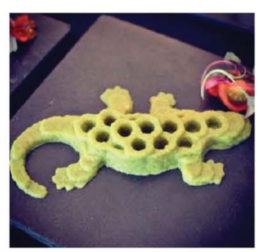
1. What do you think of using 3D-printed food in mealtimes for people with dysphagia? Would it potentially work? What barriers/facilitators to using this technology might there be?

3D Food Printing Pictures

Foodini 3D printer

Capsules inside printer

Fish and chips



Guacamole Gecko

Wafer and buttercream dessert

Hummus and olive paste pots

Chocolate ganache cup

Filled biscuit