

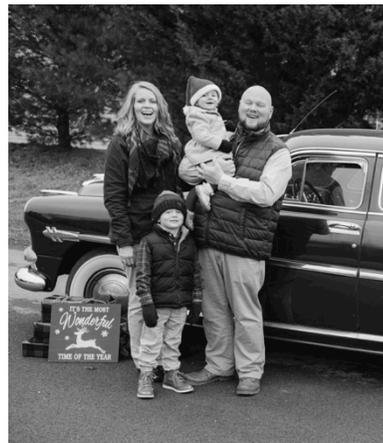
Introduction to utilizing 3D printing in Occupational Therapy

SueAnn Woods, MOT, OTR/L, CHT, CLT

Introduction and welcome!

- SueAnn Woods, MOT, OTR/L, CHT, CLT

Time	Topic	Instructional Method
0-5	Introduction & Welcome	Lecture
5-20	What is a 3D printer?	Lecture
20-40	Indications in OT, Contraindications, and Precautions	Lecture
40-55	Case Study	Multimedia
55 – 60 min	Summary, Q & A	Lecture



Learning Outcomes

- As a result of this course, participants will be able to:
 1. Identify the basics of 3D printers and filaments
 2. Identify feasibility of potential adaptive equipment or splints fabricated via 3D printers.
 3. Identify contraindications, public health concerns, and environmental concerns associated with 3D printing in OT.

What is 3D printing?

- Alternate names
 - rapid prototyping
 - Stereolithography (SLA)
 - Digital Light Processing (DLP)
 - Fused deposition Modeling (FDM)
 - Selective Laser Sintering (SLS)
 - Selective Laser Melting (SLM)
 - Electronic Beam Melting (EBM)
 - Laminated Object Manufacturing (LOM)
 - Binder Jetting (BJ)
 - Photopolymerization
 - Fused Filament Fabrication (FFM)



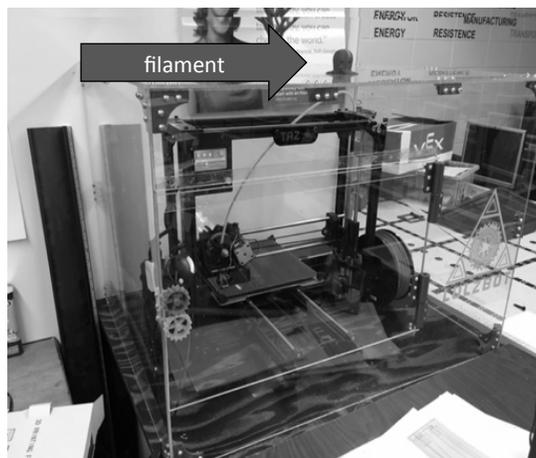
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Costs

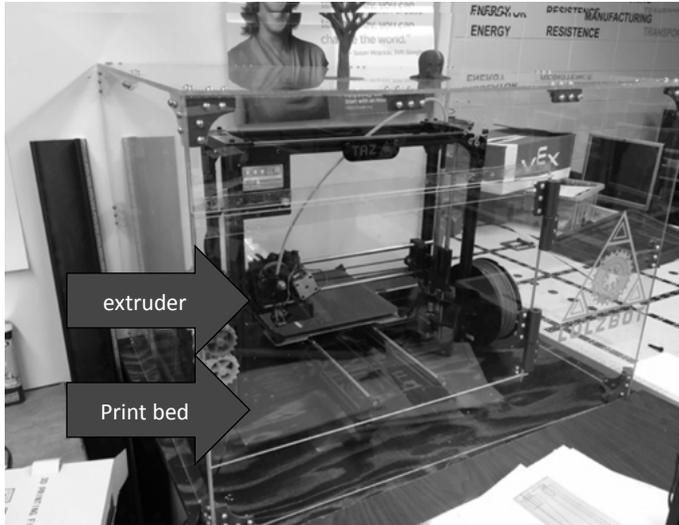
- 3D printer costs vary from \$600 for a “mini”
- \$1700 “average”
- \$6500 “deluxe”
- Spools of filament is approximately \$20-40 each
- Options:
 - Heated bed
 - enclosed

How does it work?

1. Computer design (CAD)
2. Slicing
3. Load filament onto printer
4. Send object to printer
5. Filament moves through a heated nozzle
6. Nozzle or bed moves along the route to build the object layer by layer
7. Finish the object if needed for precision



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Layer by layer



Most Common Types of Filament & Their Properties

<https://all3dp.com/pla-abs-3d-printer-filaments-compared/>

- PLA
 - Polylactic acid (PLA)
 - biodegradable thermoplastic
 - made from renewable resources like corn starch or sugarcane
 - also seen in medical implants, food packaging, and disposable tableware.
 - the main benefit of PLA is that it's easy to print.

- ABS
 - acrylonitrile butadiene styrene (ABS)
 - oil-based thermoplastic
 - also used in pipe systems, automotive trim, protective headgear, and toys (like Legos!).
 - slightly higher strength, flexibility, and durability
 - requires heated and adhesive print bed (hairspray, tape, etc.)

Infill

- Percentage
 - 20% blend or durability and material consumption
 - 50% gives good durability but uses a lot of material
- Honeycomb
- Grid

3DBenchy

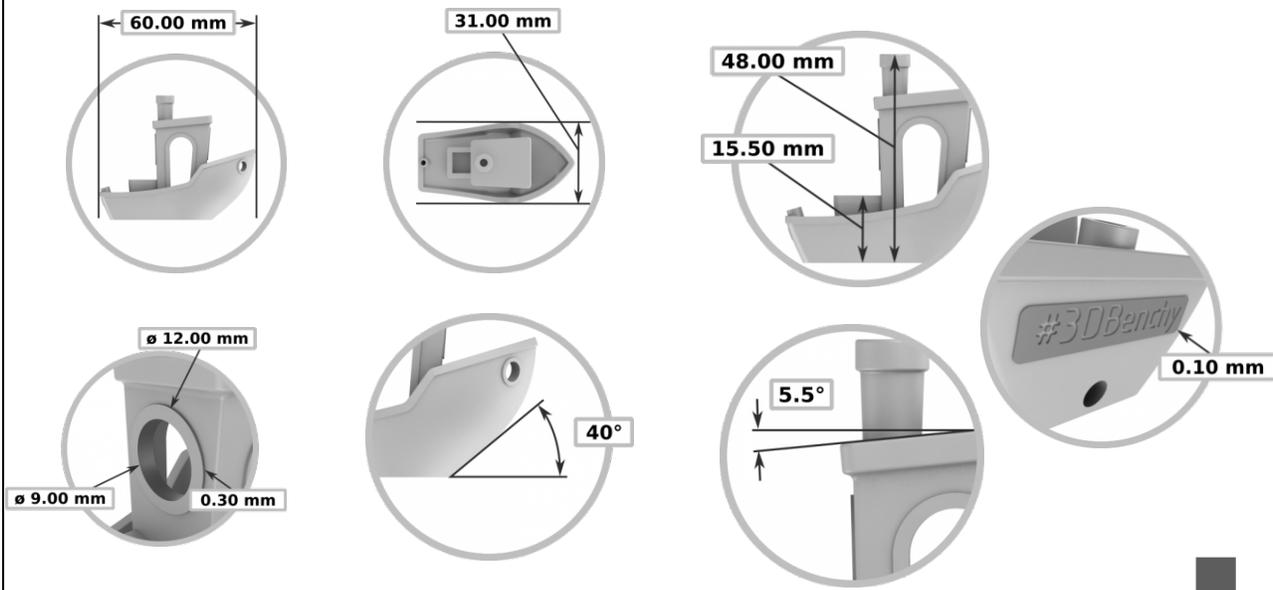
- Tugboat used for “benchmarking”
 - Accuracy
 - Warping
 - 6cm long x 3.1cm wide x 4.8cm high



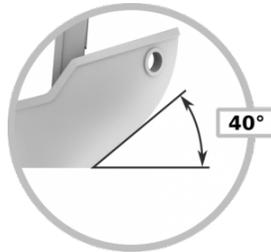
- #3DBenchy by [Creative-Tools.com](http://www.3dbenchy.com) is licensed under a [Creative Commons Attribution-NoDerivatives 4.0 International License](https://creativecommons.org/licenses/by-nd/4.0/), which states, “You are free to share — copy and redistribute the material in any medium or format for any purpose, even commercially

- <http://www.3dbenchy.com>

Youtube: #3D Benchy – The jolly 3D printing torture test



Why is 3D Benchy a torture test?



“Rapid Prototyping”

How long does 3D printing take?

Printer	Model	Print speed	
		50mm/s	100mm/s
Ultimaker 2	3DBenchy	2hr 09min	1hr 55min
Printrbot Plus V2	3DBenchy	2hr 13min	1hr 51min
Ultimaker 2	Tablet stand	6hr 23min	4hr 46min
Printrbot Plus V2	Tablet stand	6hr 27min	4hr 45min

Source: all3dp.com

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Thingiverse

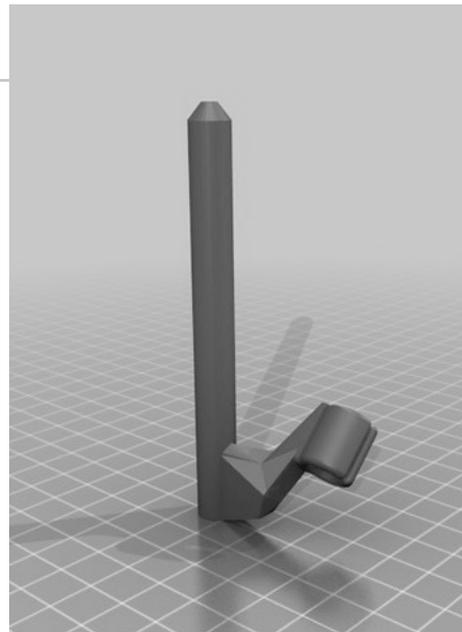
- www.thingiverse.com
- Pinterest meets 3D printing !

Possible Indications

adaptive equipment
prosthetics
orthotics

Adapted Stylus

- Designed by: Cor Winckler
- User name: xcorwin
- Location: Cape Town, South Africa
- Thing name: Occupational Therapy Stylus for Quadriplegic



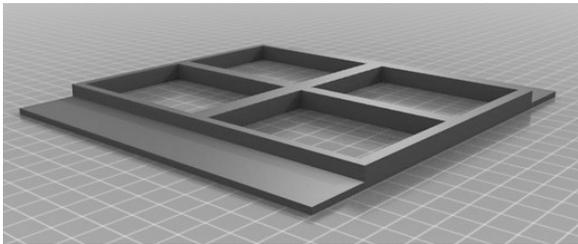
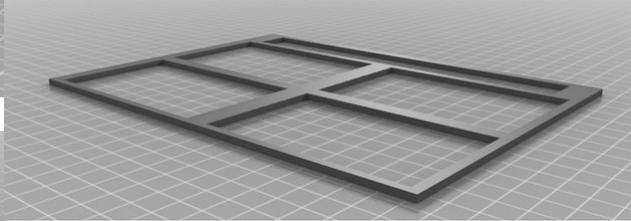
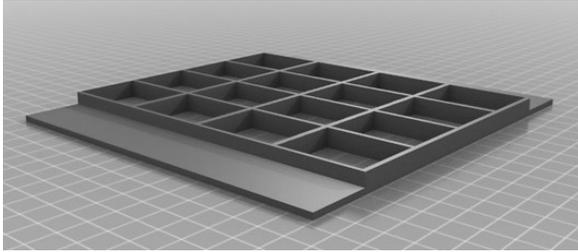
Cup holder for wheelchair tray

- Designed by: Alabama Department of Rehab Services
- User name: AlabamaDepartmentOfRehabService
s
- Location: Alabama
- Thing name: Personalized Cup Holder



Keyguard for AAC devices

- Designed by: Alabama Department of Rehab Services
- User name: AlabamaDepartmentOfRehabServices
- Location: Alabama
- Thing name:
 - Customizable Keyguard for AAC devices
 - Customizable Keyguard for the GoTalk Now iPad app



BIOT hand prosthesis

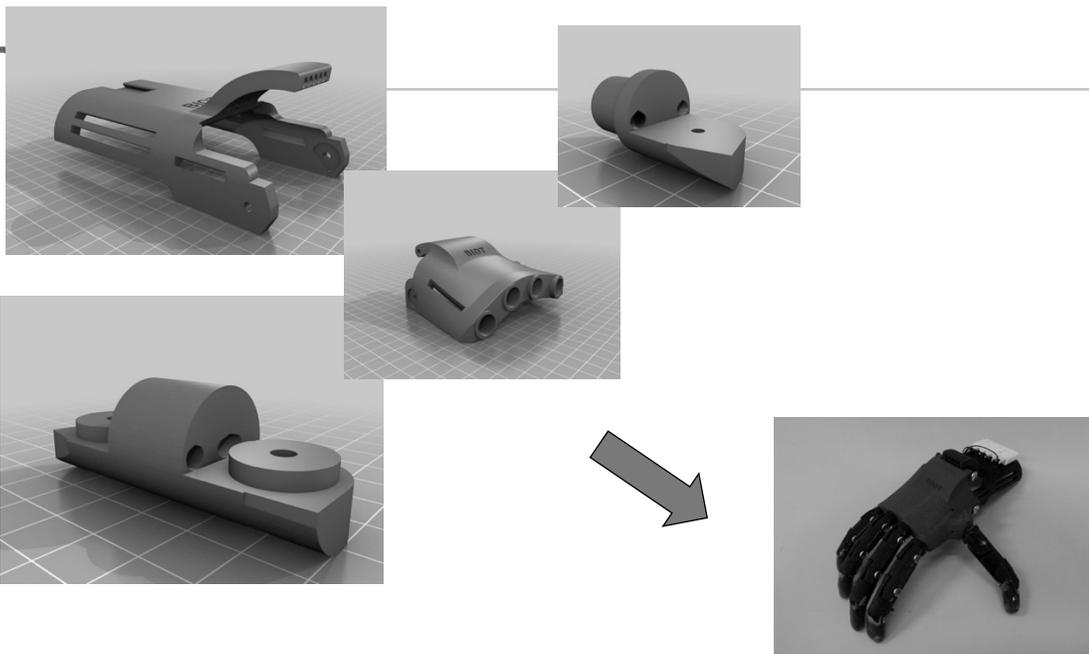
- Designed by: Cesar Augusto Martins Pereira
- User name: BiomechanicalOT
- Location: São Paulo, SP
- Thing name: BIOT hand prosthesis



BIOT hand prosthesis

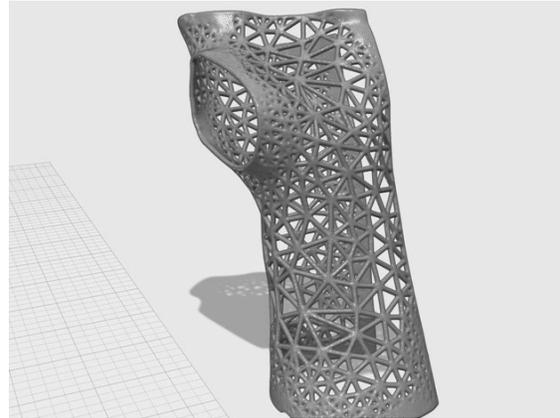
- 21 individual pieces printed and assembled with 19 screws
- Printer settings:
 - Scale according hand width using the formula
$$\text{scale} = (\text{hand width} + 2X \text{ foam padding thickness}) / 88$$
- Infill: 20%

con



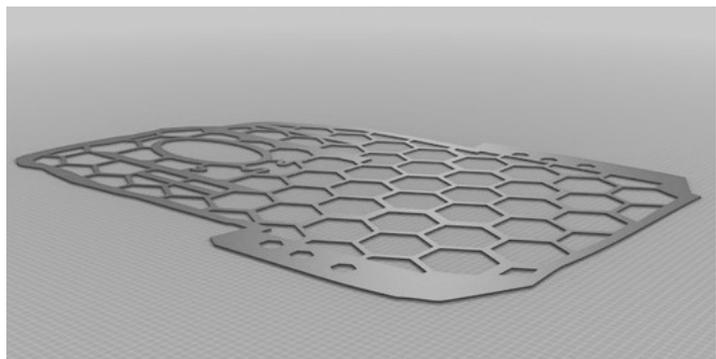
Orthotics

- Designed by: Mohd Sobh
- User name: mohd89
- Location: UAE
- Thing name: wrist-hand-splint



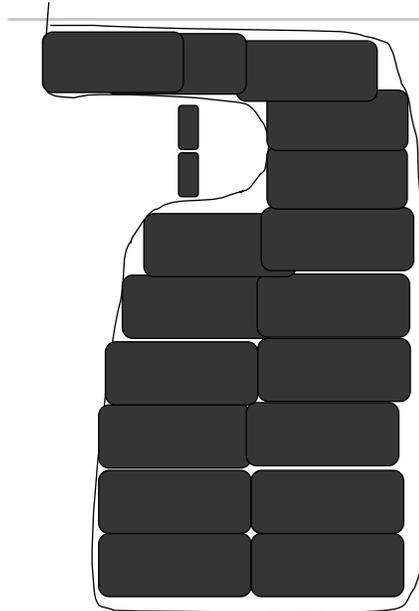
Orthotics cont'd.

- Designed by: Pablo V.
- User name: rider12
- Thing name: 3D Wrist brace/ arm cast



CONTINUED®

Wrist Immobilization Orthosis



CONTINUED®



Raft & Supports Display
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Precautions & Contraindications

Food safety

- Adapted cups or utensil
 - Bacteria build-up
 - Not dishwasher safe (and maybe not even hot drinks)
 - ABS vs PLA
- Check the MSDS sheet (SDS)
 - Material Safety Data Sheet
 - Safety Data Sheet

Public Health Concerns

- Heated plastics emit:
 - Volatile Organic Compounds (VOCs)
 - Ultrafine Particulate Matter

What are VOCs?

- Gases emitted from solids or liquids
 - Examples include
 - Paint
 - Degreaser
 - Pesticides
 - Aerosol sprays
 - Wood preservatives
 - Hobby supplies
 - Office equipment (copiers, printers, permanent markers)

Volatile Organic Compounds (VOCs)

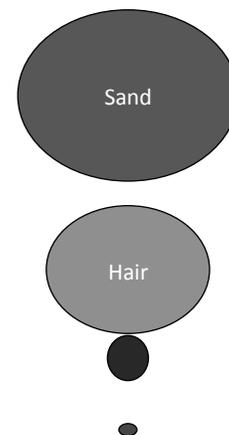
- Detectable VOCs in 3D printing
 - Caprolactam
 - Styrene
 - 20 times higher concentration than normal buildings
 - Ethanol
 - Glycerin
 - Nonane
 - Cholormethyl methyl sulfide
 - Isopropyl Palmitate
 - Acetic Acid
 - Lactide
 - Hexanal
 - Hydrazine Carbothiomide
 - Propylene Glycol
 - Ethylbenzene
 - Decane

Azimi, P., Zhao, D., Pouzet, C., Crain, N. E., & Stephens, B. (2016). Emissions of Ultrafine Particles and Volatile Organic Compounds from Commercially Available Desktop Three-Dimensional Printers with Multiple Filaments. *Environmental Science and Technology*, 50(3), 1260–1268. <https://doi.org/10.1021/acs.est.5b04983>

What are Ultrafine particulates? (UFPs)

- Particles < 100 nm (0.1 μm) in diameter
- Studies indicate that UFP deposition is greater in people with asthma than in healthy people. The total number of particles retained in the lung was 74% greater in subjects with asthma than in healthy subjects. Thus, people with asthma have a higher total respiratory dose of UFPs for a given exposure, which may contribute to their increased susceptibility to the health effects.

- Chalupa, D. C., Morrow, P. E., Oberdörster, G., Utell, M. J., & Frampton, M. W. (2004). Ultrafine particle deposition in subjects with asthma. *Environmental Health Perspectives*, 112(6), 879–882. <https://doi.org/10.1289/ehp.6851>



UFP emissions

- Particle emissions are mostly triggered by the heating process, rather than the printing process. A heated print platform eliminated 75% of particle emissions.
 - In a clean room study, the particle concentrations increased until the print was completed. The data collection continued while the clean room ventilation system was turned on and the particle concentrations were eliminated.
 - Potential role of ultrafine particles in associations between airborne particle mass and cardiovascular health
 - Inflammation → atherosclerosis → cardiovascular response
 - Both PLA and ABS have been found to be in the “high emitting range” of UFPs.
-
- Deng, Y., Cao, S. J., Chen, A., & Guo, Y. (2016). The impact of manufacturing parameters on submicron particle emissions from a desktop 3D printer in the perspective of emission reduction. *Building and Environment*, 104, 311–319. <https://doi.org/10.1016/j.buildenv.2016.05.021>
 - Stephens B., Azimi P., El Orch Z., et al. Ultrafine particle emissions from desktop 3D printers. *Atmospheric Environment* (2013), 79, 334-339
 - Zhou, Y., Kong, X., Chen, A., & Cao, S. (2015). Investigation of Ultrafine Particle Emissions of Desktop 3D Printers in the Clean Room. *Procedia Engineering*, 121(0), 506–512. <https://doi.org/10.1016/j.proeng.2015.08.1099>

Public Health Concerns

- Heated plastics emit:
 - Organic Volatile Compounds
 - Caprolactam & Styrene
 - 20 times higher concentration than normal buildings
 - Ultrafine Particulate Matter
 - Particles < 100 nm (0.1 μm) in diameter
 - Higher retention rates in those with comorbid conditions
-
- Schaper, M. M.; Thompson, R. D.; Detwiler-Okabayashi, K. A. Respiratory Responses of Mice Exposed to Thermal Decomposition Products from Polymers Heated at and Above Workplace Processing Temperatures. *Am. Ind. Hyg. Assoc. J.* 1994, 55 (10), 924–934.
 - Zitting, A.; Savolainen, H. Effects of single and repeated exposures to thermo-oxidative degradation products of poly-(acrylonitrile-butadiene-styrene) (ABS) on rat lung, liver, kidney, and brain. *Arch. Toxicol.* 1980, 46 (3–4), 295–304.

Thermoplastic Manufacturing

- This study was specifically targeted at thermoplastic manufacturers of water pipes, food packing, and thermoplastic pellets.
 - engineering controls
 - forced mechanical ventilation
 - roof fans
- Only trace levels of emissions were detectable and this process was recommended for small and medium sized enterprises.
- However, desktop 3D printers utilized in the home or office are likely not using these types of ventilation systems.

- Unwin, J., Coldwell, M. R., Keen, C., & McAlinden, J. J. (2013). Airborne emissions of carcinogens and respiratory sensitizers during thermal processing of plastics. *Annals of Occupational Hygiene*, 57(3), 399–406. <https://doi.org/10.1093/annhyg/mes078>

Take home message

- Results from a various sources suggest that caution should be used when operating in poorly ventilated spaces or without the aid of combined gas and particle filtration systems
 - Azimi, P., Zhao, D., Pouzet, C., Crain, N. E., & Stephens, B. (2016). Emissions of Ultrafine Particles and Volatile Organic Compounds from Commercially Available Desktop Three-Dimensional Printers with Multiple Filaments. *Environmental Science and Technology*, 50(3), 1260–1268. <https://doi.org/10.1021/acs.est.5b04983>
 - Stephens B., Azimi P., El Orch Z., et al. Ultrafine particle emissions from desktop 3D printers. *Atmospheric Environment* (2013), 79, 334-339, p.339.
- The most effective combination is thought to be the use of an enclosure, an enclosure ventilation fan, and a HEPA filter. This study didn't investigate whether this method removed the aforementioned VOCs.
 - Kwon, O., Yoon, C., Ham, S., Park, J., Lee, J., Yoo, D., & Kim, Y. (2017). Characterization and Control of Nanoparticle Emission during 3D Printing. *Environmental Science and Technology*, 51(18), 10357–10368. <http://doi.org/10.1021/acs.est.7b01454>

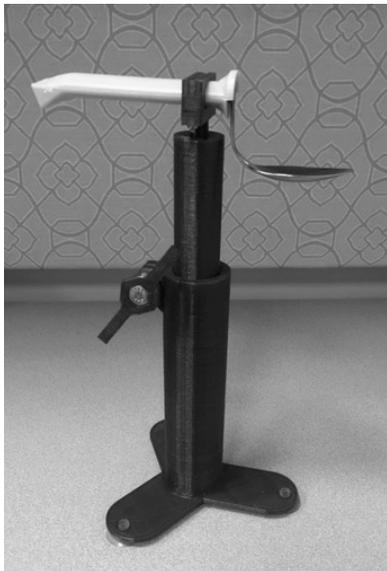
Case Study

13 year old boy with arthrogryposis

UE limited function

LE not affected, all joints WNL

Goal: self feeding at the table with family



CONTINUED

Dinner Spinner version 2



Spoon details:

Sammons Preston Plastic Handle Swivel Teaspoon, Adaptive Utensils for Elderly, Arthritis, Shaking Hands, 6" Long Swiveling Spoon for Eating with Good Grip for Limited Muscle Control

Purchased from Amazon for \$20.10

CONTINUED



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Thank you!

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