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Application of 3D Printing in the Construction of Burr Hole Ring for Deep Brain Stimulation Implants

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Dear Editors:

We are pleasure to accept the invitation from Editor Aaron Berard, and submit the enclosed manuscript entitled ***Application of 3D Printing in the Construction of Deep Brain Stimulation Implant*****s,** which we would like to be considered for publication in ***Journal of Visualized Experiments (JoVE)***. No conflict of interest exits in the submission of this manuscript, and manuscript is approved by all authors for publication. Recently, we published ***3-D Printing for Constructing the Burr Hole Ring of Lead Fixation Device in Deep Brain Stimulation (***J Clin Neurosci. 2018 Dec;58:229-233. doi: 10.1016/j.jocn.2018.10.086. Epub 2018 Oct 24***),*** which showed good effects of our novel methods. To share the methods in detail in the video format, I would like to declare on behalf of my co-authors that the work prepared was not under consideration for publication elsewhere, in whole or in part. All of 9 authors listed have approved the manuscript that is enclosed.

3D printing has been widely applied in the medical field since 1980s. Especially in the field of surgery, 3D printing has been gradually used in preoperative simulation, anatomical learning and surgical training. This raises the possibility of using 3D printing to construct a neurosurgical implant. Our study took the construction of the burr hole ring as an example, we described the process of using softwares like computer aided design (CAD), Pro/E and 3D printer to construct physical products. A total of 3 steps are required, the drawing of 2D - image of burr hole ring, then the construction of 3D – image of burr hole ring. Finally, using 3D printer to print the physical model of burr hole ring. Our study shows that the burr hole ring made of carbon fiber can be rapidly and accurately molded by 3D printing. Our study indicated that both CAD and Pro/E solfwares can be used to construct the burr hole ring via integrating with the clinical imaging data and further applied 3D printing to make the individualized consumables.

I hope this paper is suitable for ***JoVE*** in the Section of ***Behavior.***

We deeply appreciate your consideration of our manuscript, and we look forward to receiving comments from the reviewers. If you have any queries, please don't hesitate to contact me at the address below.

Thank you and best regards.

Yours sincerely,
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TITLE:

Application of 3D Printing in the Construction of Burr Hole Ring for Deep Brain Stimulation Implants

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KEYWORDS:

3D printing, additive manufacturing, computer-aided design, deep brain stimulation, humans, neurosurgery

SUMMARY:

Here, we present a protocol to demonstrate 3D printing in the construction of deep brain stimulation implants.

ABSTRACT:

3D printing has been widely applied in the medical field since the 1980s, especially in surgery, such as preoperative simulation, anatomical learning and surgical training. This raises the possibility of using 3D printing to construct a neurosurgical implant. Our previous works took the construction of the burr hole ring as an example, described the process of using softwares like computer aided design (CAD), Pro/Engineer (Pro/E) and 3D printer to construct physical products. That is, a total of three steps are required, the drawing of 2D-image, the construction of 3D-image of burr hole ring, and using a 3D printer to print the physical model of burr hole ring. This protocol shows that the burr hole ring made of carbon fiber can be rapidly and accurately molded by 3D

printing. It indicated that both CAD and Pro/E softwares can be used to construct the burr hole ring via integrating with the clinical imaging data and further applied 3D printing to make the individual consumables.

INTRODUCTION:

3D printing has been applied in the medical field since the 1980s, especially in surgery for preoperative simulation, anatomical learning and surgical training[1]. For example, in cerebrovascular operations, preoperative simulation can be conducted by using 3D printed vascular models [2]. With the development of 3D printing, the texture, temperature, structure and weight of cerebral blood vessels can be simulated to the greatest extent of clinical scenarios. Trainees can perform surgical operations such as cutting and clamping on such models. This training is very important for the surgeons[3-5]. Currently, titanium patches formed by 3D printing have also gradually been applied[6], since the skull prostheses developed by 3D printing after imaging and reconstruction are highly conformal. However, the development and application of 3D printing in neurosurgery is still limited.

The burr hole ring, as a part of the lead fixation device, has been widely used in deep brain stimulation (DBS)[7-10]. However, current burr hole rings are made by medical device manufacturers according to the unified specifications and dimensions. This standard burr hole ring is not always suitable for all conditions, such as skull malformation and scalp atrophy. It may increase the uncertainties of operation and reduce the acurracy. The emergence of 3D printing makes it possible to develop individualized burr hole rings for patients in clinical scenarios[5]. At the same time, the burr hole ring, which is not easy to obtain, is not conducive to extensive preoperative demonstration and surgical training[1].

To address the problems mentioned above, we proposed to construct a burr hole ring with 3D printing. A previous study in our lab described an innovative burr hole ring for DBS[11]. In this study, this innovative burr hole ring will be regarded as an excellent example to exhibit the detailed production process. Therefore, the purpose of this study is to provide a modeling process and a detailed technical process of building a solid burr hole ring using 3D printing.

PROTOCOL:

1. Drawing a two dimensional (2D)-image of a burr hole ring

1.1. Open the 2D computer aided design (CAD) software and then create a graphical document.

1.2. Click **Draw | Line** and draw a reference point with a solid line on the drawing. Click **Modify | Offset**, and type the specific offset distance in the command line.

1.3. Click on the object and press by the left mouse button to create a solid line. Click **Modify | Trim**, select the area to be trimmed and click on the extra line.

1.4. Take the inner burr hole ring for example, draw three different views of the inner ring based on the predetermined size in the CAD software. First, draw the front view and modify the graph carefully until it matches the structure expected (**Figure 1d**).

1.5. Draw the top view by clicking **Draw | Line** to construct the reference point first and then click on **Draw | Circle | Center**, **Diameter**, and input the quantitative value of specific radius of circle or diameter in the command window. Click on the center of the reference point to form a circle (**Figure 1f**).

1.6. Draw the left view of the inner burr hole ring with the same approach as that of the front view (**Figure 1e**).

1.7. Click on **Dimension | Diameter**, and then click on the circumference to mark the diameter of the circle (**Figure 1f**).

1.8. Click on **Dimension | Linear** and mark the length and thickness of all associated structures (**Figure 1d,e**). Click **Dimension | Radius** to mark the angle of the chamber (**Figure 1d**).

1.9. Using the same protocol, construct two-dimensional drawings of the outer burr hole ring, and mark the actual size and the labeling (**Figure 1a–c**).

1.10. Add technical requirements of the production process, including strength, toughness and lack of cracks. Moreover, smoothing of the outer wall is needed.

1.11. Clink on **Save** to save the 2D-image of the burr hole ring.

NOTE: All of these structures mentioned above are in the units of millimeters (mm).

2. Construction of a 3D-image of the burr hole ring

2.1. Start the 3D drawing software (see the **Table of Materials**). Select **New | Part | Solid** and uncheck **using the default template**. Select **part_solid** in new file options and click on **Ok** to create a new interface for setting up a physical part model.

2.2. Click on **Part feature** in the menu manager on the right and select **Create | Solid | Add sheet**. In the **SOLID** drop-down menu, select **Rotate | Done**. Click on the trace of the preliminary sketch. Select the "front" plane as the sketch plane, then click **default** under **SKET VIEW**.

2.3. Select the dotted line on the right toolbar of the window and draw the top section of the part in the two-dimensional sketch. The specific size shall be subject to the two-dimensional drawing. Then click **Conform**, and select **Done** in the **Protrusion** window of protrusion. Click on the **Datum plane** icon.

2.4. In menu manager, select **Create | Solid | Add sheet**, and **Rotate | Done**. Click **Bilateral** in the properties menu and click **Done**.

2.5. Click on **Front | Forward | Default** and then **Datum plane | Dotted Line** to construct the cross section of the hook of the outer burr hole ring. Then click **Conform** followed by **Done** in menu manager. Input "50: in **Angle in indicated direction[45.0000]**, and then click **Done** in the **Protrusion** window and finally, click on the **Coloring** button.

NOTE: The unit of the angle is degree (°).

2.6. Select **Redefine** in the part feature and click the line structure of the hook. Input the command **Section | Define | Sketch**.

2.7. Click the **Dotted line** icon, create two square embossments on the hook section, then input command **OK | Done | Coloring**.

2.8 Click the **Datum axis** icon, then input the command **Insert a datum | Cross**, click the center axis of the line structure, click **Angle** in datum plane, and then click the "front" plane in the line structure view. Click **input value** in the **offset** menu. Input "−45" in "**Angle in indicated direction[45.0000]**.

NOTE: The unit of the angle is degree (°).

2.9. Click on **Features | Copy | Mirror**. Click on the hook as the object and input command **Done select | Done**. Click the datum plane to complete the copy. Similarly, the remaining two hooks are copied in this way. Click on **Create concentric circle** to construct a circle with a radius of 7.23 mm, click the **Segmentation of primitives at selected points** icon to remove the unnecessary lines of the circle.

2.10. Click the **Solid line** button in the right toolbar to create a complete outer wall section. Then input the command **OK | Done**.

NOTE: The unit of the radius is millimeter (mm).

2.11. Input "4" in **Enter depth**, then click on **Coloring**. Input the command **Mirror | Done**. Then click on the object and click **Done**. Click the datum plane to complete the copy.

2.12. Input the command **Copy | Mirror | Done**, and select two outer walls in different directions, click **Done** to conform. Click the datum plane to complete the copy.

2.13. Input the command **View | Model Settings | Color and appearance | Add**. Adjust the RGB color slider and adjust the color to brown to show the graphic details more visually. Then input the command **Close | Settings | OK**.

2.14. Click the button **Eliminating hidden lines**, click the **Create concentric circle**, continue to create an outer edge on the outer wall, click the **Segmentation of primitives at selected points** button to remove excess lines, and click the **Solid line** button to connect the newly added outer edge into a complete section. Click **Ok**.

2.15. Input "0.8" in **Inter depth**. Click **Ok** in the **Protrusion** window. In menu manager, input the command **Copy | Mirror | Done**. Click the object and click **done**. Input the command **Generate benchmark | Offset**.

NOTE: The unit of the depth is millimeter (mm).

2.16. Click the **Input value** in the **Offset** and enter "0.4" as the **Isometric of the specified direction**, then click **Done**.

NOTE: The unit of the offset is millimeter (mm).

2.17. Input the command **Copy | Mirror | Done**, click the outer wall. Input the command **Done select | Done**. Click **Done select** and click **Done**. Click the datum of the image to complete the copy. In this way, the mirror operation of the outer wall and the square embossing is completed respectively.

2.18. Input the command **File | Copy**, select save format as STL (*stl) in the part type drop-down menu, enter part number and click **Ok**.

2.19. In the **Output STL** dialog box, adjust the chord height to 0.006 and the angle control to 0.00001. Input the command **Apply | OK**.

2.20. Use the same methods as above to build the 3D image of the inner ring.

3. Using 3D printer to print the physical model of burr hole ring

3.1. Open the model detecting software, input the command **Project | Open**, choose one STL file in the **Open file** pop-up dialog box, then click **Open**. In this software, a warning will appear if defects are detected in this model (**Figure 3**). If found, repair the model before printing. If there are no defects, click **Output**.

3.2. After confirming that the outer ring is complete, input the command **Part | Export part | as STL | Save**. Use the above instructions to detect the defects of the inner ring.

3.3. Following model detection, the printed path needs to be designed. Open the slicing software, click **File | Load model file**, click on one STL file and click **Open** to import.

3.4. Click the left mouse button to choose the moving track of the part, adjust the position of parts. On the left side of the screen, set the print speed to 30 mm/s, printing temperature to 210 °C and bed temperature to 80 °C (**Figure 4**).

3.5. Click **Toolpath to SD** to save the file in Gcode format to generate printed path (**Figure 3**).

3.6. Start the 3D printers, click the **Preheating** button on the main interface, set the preheat temperature of the bed to 80 °C and the nozzle temperature to 210 °C. Click **Print** when the temperature rises to the preset value, select the target file and click **Confirm** to start printing.

3.7. The outer ring will be printed first (**Figure 5a**). After the bottom supporting grid has been constructed, the printing nozzle begins to construct the outer ring vertically layer by layer (**Figure 5b–d**). This process takes about 13 min.

3.8. After the outer ring is formed, the printer nozzle continues to make the inner ring on the right side (**Figure 5c,d**), which takes about 8 min.

3.9. Remove both parts from the platform after cooling and being formed (**Figure 5e,f**).

4. Measurement of absolute error

4.1. To measure the absolute error, select five printed parts randomly. Measure and record the parameters of each part with Vernier calipers. Choose the measurement accuracy at 0.02 mm.

4.2. Calculate the mean error of each part and the error range of the absolute error (**Figure 6a,b**).

REPRESENTATIVE RESULTS:

Three views of 2D images were built through commercial CAD software (see the **Table of Materials**). In these images, practical size and technical requirements have also been added (**Figure 1**). Further, three-dimensional data were constructed in (**Figure 2**) and saved in STL format (**Figure 3**). As presented in **Figure 4**, solid parts were built on the platform of the printer. Choosing five groups of these parts, absolute error and error range was calculated (**Figure 6 a,b**). The result showed that, in outer ring, the maximum absolute error and minimum absolute error were found in the outside diameter of the waist and in the thickness of the top respectively. In the inner ring, the maximum absolute error and the minimum absolute error were found in the inside diameter and thickness of the top respectively. The total error range was [0.00, 0.59] (**Figure 6 a,b**).

The STL file is further be converted to Gcode file in the slicing solfware. After that, the Gcode file is transmitted into the 3D printer using an SD card. In the 3D printer, carbon fiber was fed through feeding port. A temperature control unit was used to control the melting of the carbon fiber and the nozzle was used to control the release of printing material and construct the solid model.

FIGURES LEGENDS:

Figure 1: 2D image of burr hole ring. (**a–c**) 2D views (front view, left view and top view, respectively) of the outer ring. (**d–f**) 2D views (front view, left view and top, view respectively) of the inner ring. Unit: mm.

Figure 2: 3D image of the burr hole ring. (**a–c**) 3D views (front view, left view and top view, respectively) of the outer ring. (**d–f**) 3D views (front view, left view and top view, respectively) of the inner ring.

Figure 3: The flowchart for constructing a burr hole ring via 3D printing.

Figure 4: The process of slicing the burr hole ring by slicing solfware. In the slicing solfware, the STL model was sliced into 0.1 mm thick layers (the black solid arrows). Parameters such as speed and temperature were set (red box) as follows: printing speed at 30 mm/s, printing temperature at 210 °C and bed temperature at 80 °C. Finally, we pressed **Save toolpath**, and the STL file was converted into Gcode files for 3D printing directly.

Figure 5: The example of constructing burr hole ring via 3D printing. (**a**)The solid arrow on the left indicated the nozzle and the solid arrow on the right side showed the touching buildplate, which was used to host the solid model. (**b**) The outer ring (the solid arrow) was constructed on the touching buildplate. (**c**) The inner ring was built on the touching builplate (the solid arrow). (**d**) The inner ring was built on the right side of the bed (the solid arrow). (**e–f**) Example of inner ring and the outer ring (the solid arrow) after polishing.

Figure 6: Measurement of absolute error. (**a**) Absolute error and error range of outer rings (AE = | MV – SV |; main structures: (1) outer diameter of the top; (2) outer diameter of the waist; (3) thickness of main body; (4) thickness of the top; (5) width of the hook; (6) inner diameter of the top). (**b**) Absolute error and error range of inner rings (AE = | MV – SV |; main structures: (1) outside diameter of the top; (2) outer diameter of the bottom; (3) inner diameter; (4) total height; (5) thickness of the bottom; (6) thickness of the top. P = part, MV = measured values, SV = standard values, AE = absolute error, ER = error range. Accuracy = 0.02mm; Unit =mm.

DISCUSSION:

These results showed that the software used were practicable to build 3D models of burr hole rings (**Figure 1 and Figure 2**), and 3D printing can be used to build solid models with designated materials (**Figure 4**). In terms of the size of the solid model, there was an absolute error from 0 to 0.59 mm determined through the measurement made by Vernier calipers (**Figure 6**). To some extent, the error is unavoidable since such absolute error comes from many factors, such as the quality of the printing instrument. Industrial printers can have better precision. In addition, when building smaller and more precise parts, the absolute error is more obvious. In general, as shown in **Figure 3**, the process that constructed the model and further formed the solid model by 3D printing is effective and feasible. Although there is an absolute error, such error can be reduced by improving the quality of the printers and accurately adjusting the printing parameters.

An innovative burr hole ring for DBS was published previously[11]. In this study, the same model was applied as an example to further demonstrate the systematic process of making the related implants. Currently, in the limited clinical application of 3D printing, model building generally adopts two methods: Firstly, CAD modeling has been used to generate 3D models for further 3D printing operations[12]. Secondly, imaging data (like in the format of DICOM) has been used to reconstruct the bone structure of patients in three dimensional models according to CT and MRI data. After rendering, the data could be further converted into editable STL files, and then the highly simulated anatomical structure can be produced by 3D printing[12-14]. Similarly, patching or implanting materials that are highly suitable for morphology can be designed according to the anatomical structure of three dimensional reconstruction[15-17]. This method has been applied in cranioplasty. A previous study showed titanium skull patches constructed by 3D printing technology[6]. Although using 3D printing technology to construct burr hole rings through credible flow visualization in this study in possible, this modeling method has certain limitations in practice.

Being different from the traditional production of burr hole rings, this study proposed to use 3D printing to construct these implantable parts. In fact, traditional products are mostly uniform in size, which does not apply to some patients with skull shape variation and scalp atrophy. The application of 3D printing would potentially provide the implants customized for different patients. Previous studies have proposed and implemented the application of 3D printing to produce skull fragments for skull defect repairment, and has showed its permanent effect[6]. The efficacy of DBS for functional neurosurgical diseases has been widely recognized (such as Parkinson's disease, dyskinesia)[18-20], but the popularity of this treatment is limited, which may be the result of economic burden caused by high consumable costs. Products made by 3D printing have the advantages of high production efficiency, low cost and customization, which makes 3D printing of great potential in the field. The development and application of this technology may provide more patients with an opportunity to receive DBS surgery. However, there are few reports on the use of 3D printing to produce consumables for DBS in the literature.

Moreover, the burr hole ring constructed by 3D printing can have other advantages. This rapid prototyping product can be used for preoperative demonstration, which will better inform patients and their families about the procedure of electrode implantation and enhance doctor-patient communication effectively. Clinicians can carry out preoperative simulation and surgical training through 3D printed products to maximize the simulation of DBS surgery, which will effectively improve their surgical skills. In the surgical treatment of cerebrovascular tumors and cranioplasty, 3D printed products have been applied to surgical training [2,5].

This study used carbon fiber, which has good strength and toughness, as the printing material to show the production process of 3D printing. In practice, many factors of implant material should be considered. Firstly, whether the implant has excellent disinfection performance and can keep its properties unchanged under ethylene oxide and hot steam for a long time[12]. Secondly, implants need to have good biocompatibility and can be placed for a long time without rejectiong by the body. Thirdly, implants need to have excellent mechanical strength, toughness and chemical resistance.

In this study, the construction of a burr hole ring as an example was demonstrated to systematically describe the process from modeling to 3D printing. This is a complete process example. In the future, the use of CAD software, imaging data (e.g., DICOM) and 3D printing to construct the burr hole ring should be encouraged. As mentioned above, 3D reconstruction of DICOM data obtained by imaging can be further converted into STL files that can be used for 3D printing. This is also the mainstream modeling method in clinical scenarios [12,13]. This method has not been applied in the DBS surgery.

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DISCLOSURES:

The authors have nothing to disclose.

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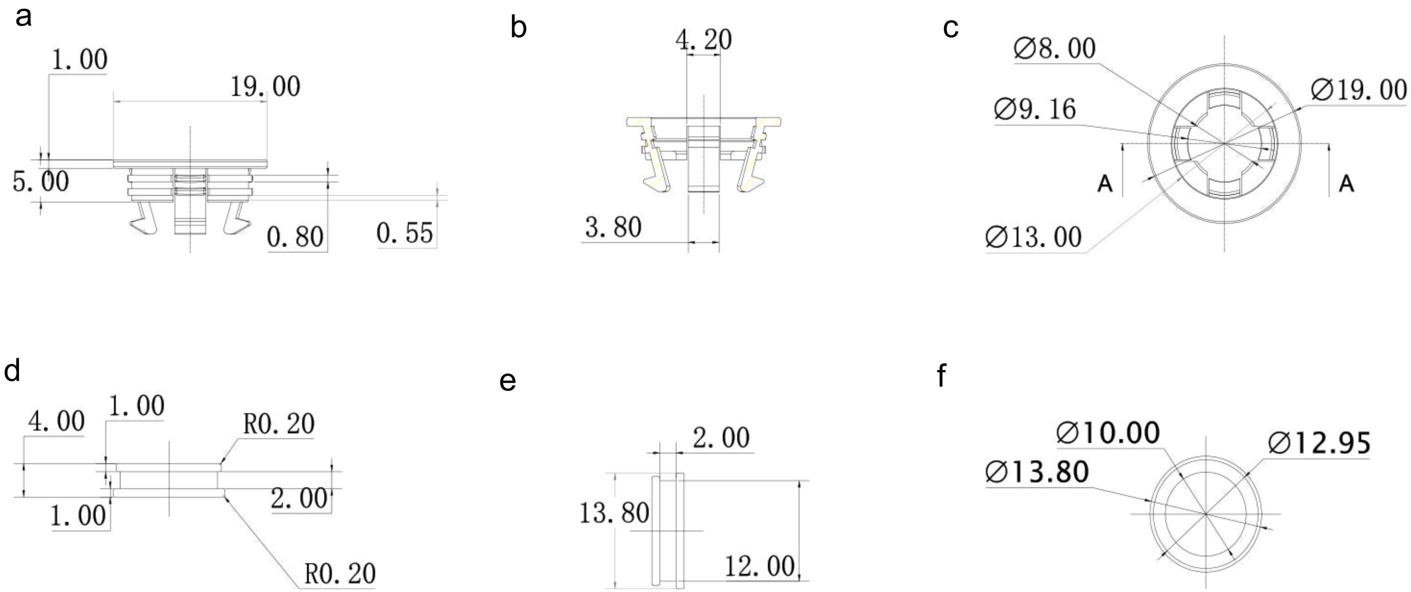
Figure1


a
1. 00
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b
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3. 80
c
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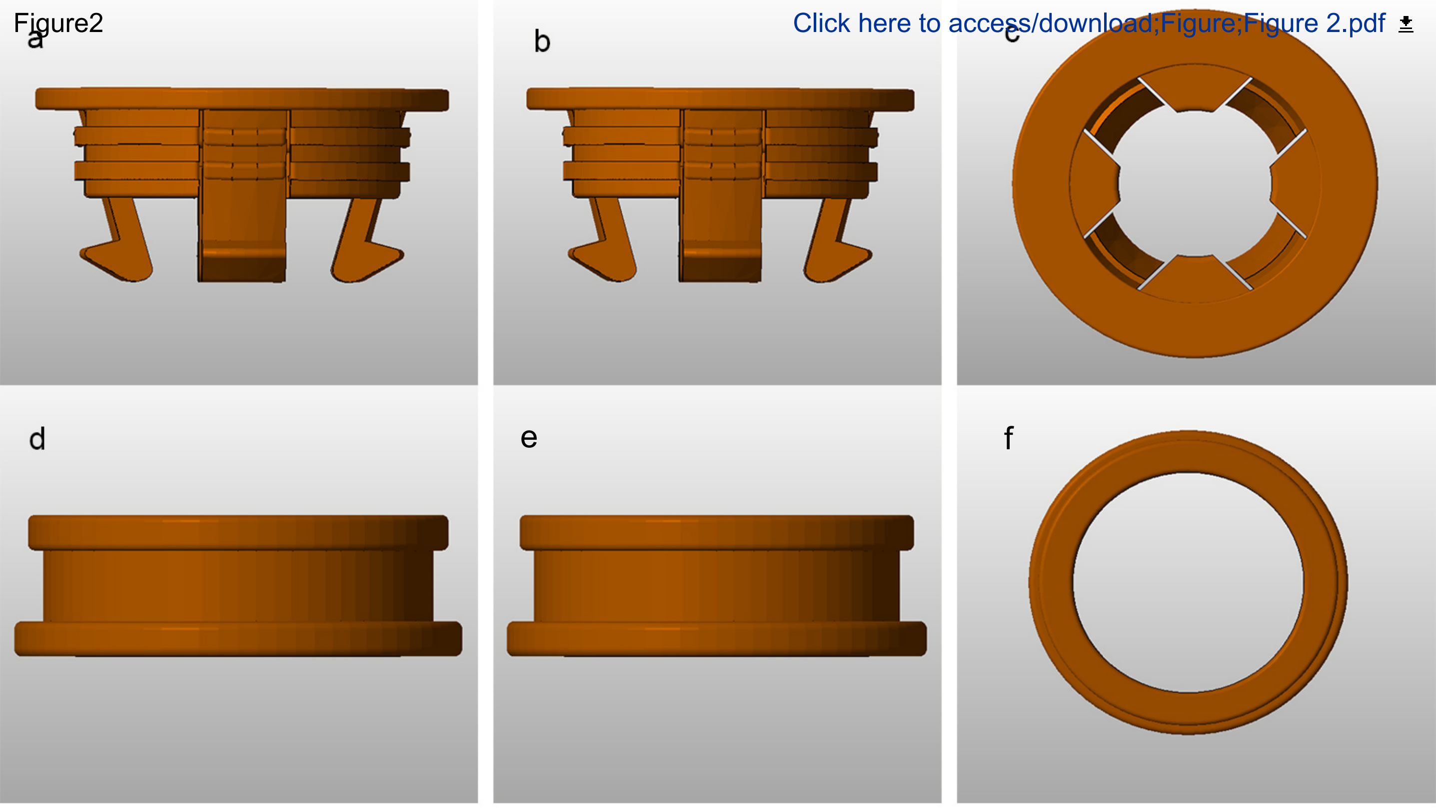
Figure2



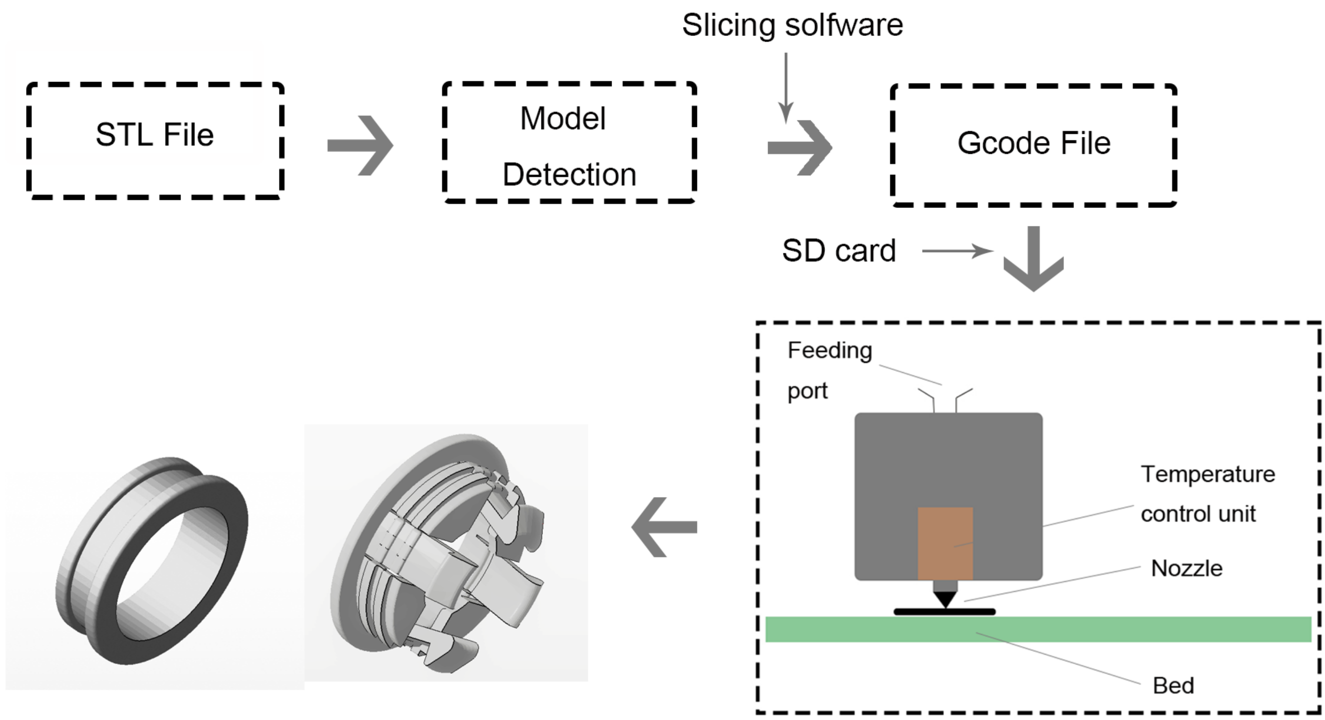
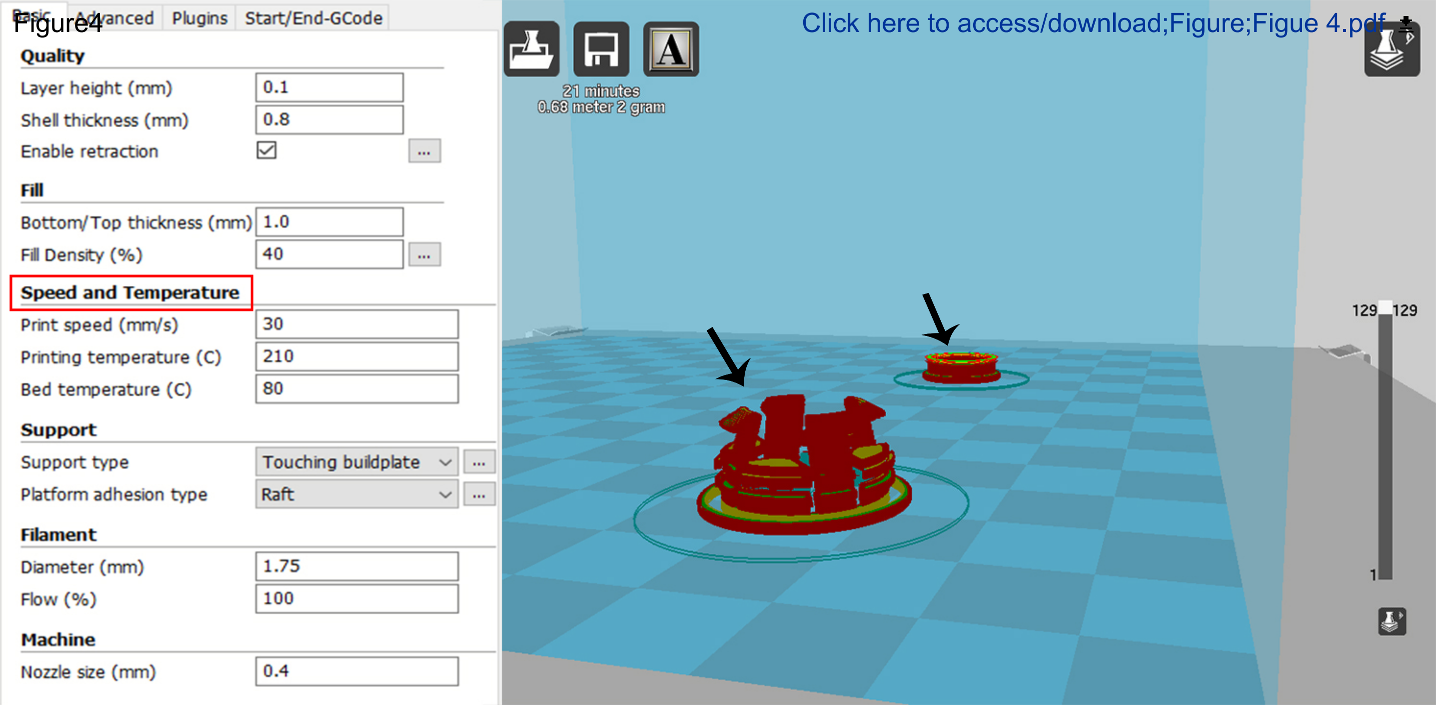
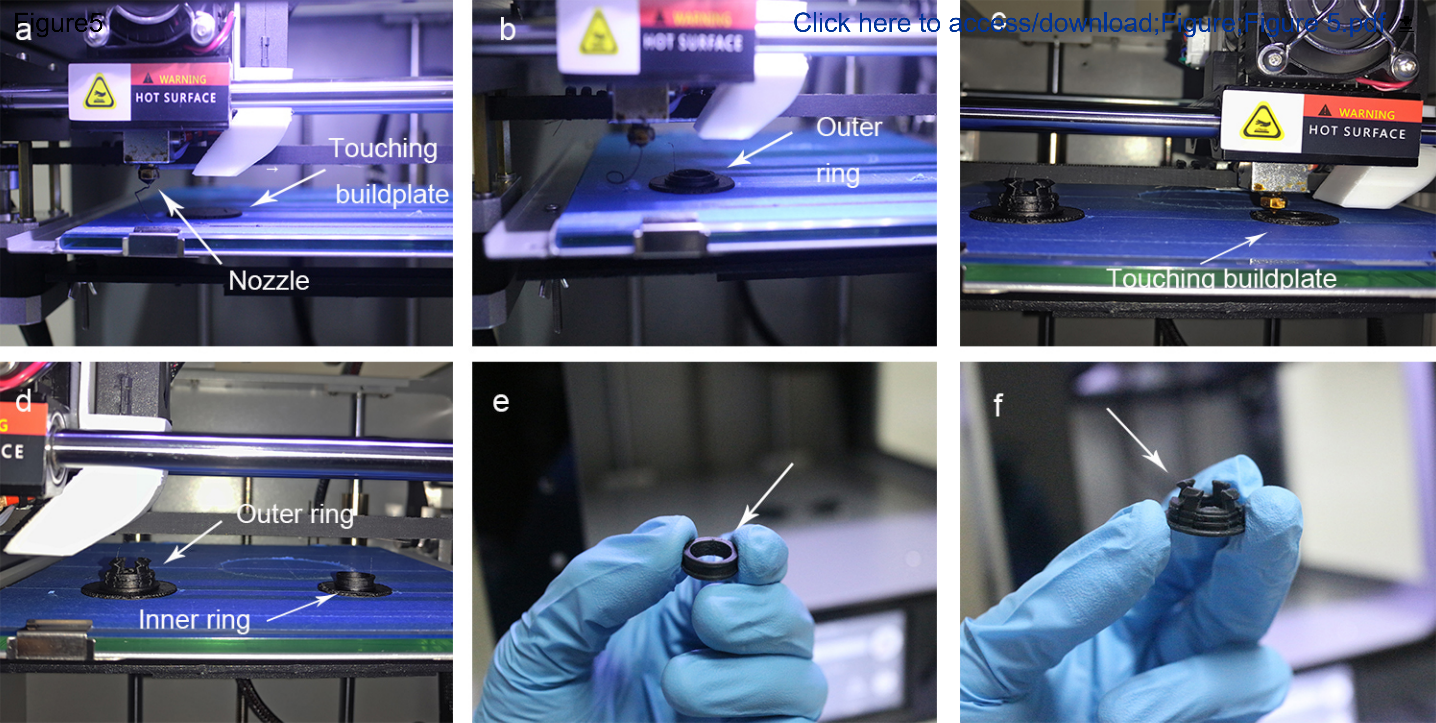

Slicing solfware
STL File
Model
Detection
Gcode File
SD card
Feeding
port
Temperature
control unit
Nozzle
Bed

Figure4

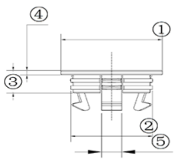


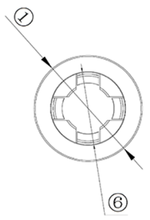
Click here to access/download;Figure;Figue 4.pdf

Figure5


a
WARNING
HOT SURFACE
Touching
buildplate
Nozzle
b
WARNING
HOT SURFACE
Outer
ring
c
WARNING
HOT SURFACE
Touching buildplate
d
Outer ring
Inner ring
e
f

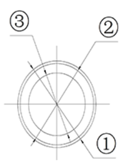
a

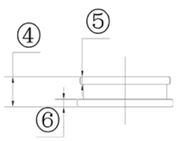




P	MV	SV	AE	ER	P	MV	SV	AE	ER
	18.88		0.18			1.00		0.00	
	18.96		0.10			1.00		0.00	
①	18.82	19.06	0.24	[0.1, 0.26]	④	1.00	1.00	0.00	[0.00, 0.00]
	18.80		0.22			1.00		0.00	
	18.84		0.26			1.00		0.00	
	15.92		0.59			4.00		0.20	
	15.84		0.51			3.98		0.18	
②	15.82	15.33	0.49	[0.49, 0.59]	⑤	3.94	3.80	0.14	[0.14, 0.20]
	15.88		0.55			3.96		0.16	
	15.90		0.57			3.94		0.14	
	5.08		0.08			12.90		0.10	
	5.04		0.04			12.98		0.02	
③	5.00	5.00	0.00	[0.00, 0.14]	⑥	12.96	13.00	0.04	[0.02, 0.10]
	5.14		0.14			12.96		0.04	
	5.08		0.08			12.94		0.06	

b





P	MV	SV	AE	ER	P	MV	SV	AE	ER
	13.64		0.16			4.08		0.08	
①	13.72		0.08			4.00		0.00	
	13.62	13.80	0.18	[0.08, 0.26]	④	4.04	4.00	0.04	[0.00, 0.08]
	13.70		0.10			4.06		0.06	
	13.54		0.26			4.08		0.08	
	12.80		0.15			1.00		0.00	
	12.82		0.13			1.00		0.00	
②	12.96	12.95	0.01	[0.01, 0.19]	⑤	0.96	1.00	0.04	[0.04, 0.08]
	12.86		0.09			1.08		0.08	
	12.76		0.19			1.00		0.00	
	9.58		0.42			1.00		0.00	
	9.82		0.28			1.00		0.00	
③	9.90	10.00	0.10	[0.00, 0.42]	⑥	1.02	1.00	0.02	[0.00, 0.02]
	9.88		0.02			1.06		0.06	
	10.00		0.00			0.98		0.02	

Name of Material/Equipment	Company	Catalog Number	Comments/Description
Adobe Photoshop Version 14.0	Adobe System, US	_	Only available with a paid sub
Allcct 3D printer	Allcct technology co., LTD, WuHan, China	201807A794124CN	
Allcct_YinKe_V1.1	Allcct technology co., LTD, WuHan, China		The software is provided by t
AutoCAD 2004	Autodesk co., LTD, US	666-12345678	Software for 2D models
Carbon Fibre	Allcct technology co., LTD, WuHan, China	PLA175Ø5181Ø3ØB	The material is provided by th
Netfabb Studio Basic 4.9	Autodesk co., LTD, US	-	The software is provided by a
Pro/E 2001	Parametric Technology Corporation, PTC, US	_	Software for 3D models; Only
Vernier caliper	Beijing Blue Light Machinery Electricity Instrument Co,. LTD, China	GB/T 1214.1-1996	

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ı 3D printer manufacturer and is open to access

/ available with a paid subscription.

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Author(s):	Jiazhi Chen, Xinyu Chen, Siyuan Lv , Yuzhen Zhang, Hao Long, Kaijun Yang, Songtao Qi, Wangming Zhang, Jun Wang

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CORRESPONDING AUTHOR

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Department:	Neurosurgery
Institution:	Nanfang Hospital, Southern Medical University
Title:	Dr.
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Re: JoVE59560R3 Application of 3D Printing in the Construction of Deep Brain Stimulation Implants. [EMID:ceb38ceead9081c1]

Dear Editor,

We really appreciate your response and comments on our manuscript. We sincerely apologize for the great time it has taken us to respond to these comments, and hope that a revised version of the manuscript will still be considered by your precious JoVE. We have modified the paper in response to the extensive and insightful comments. We will respond to the comments point counter point.

Editorial comments:

Please note that you are within our videographer's network and having us come to film and produce your video will greatly increase its quality and production value. Please let me know if you would like to switch from an author produced video to a JoVE produced video.

It sounds like the narration audio is different from the last submission. The audio now is more heavily compressed and has very harsh compression/noise on anything sibilant (i.e. all of the 'S' sounds). This makes the voice harder to understand and makes for an uncomfortable listening experience for the audience. The audio quality needs to meet the level of the previous December 24 submission.

Please upload the revised video file here:

https://www.dropbox.com/request/4pmoq6l4ZO2NR14LpCW8?oref=e

Please perform thorough language editing of the manuscript or employ a professional editing service.

Response:

We try all our best to improve the quality of our video, and redo the Introduction part. However, it is impossible to make sure that the quality of the video as good as the one produced by you. Therefore, we upload the the new version of video with the narration script, which may help you narrate for us. Please polish our video with JoVE produced video based on our video. In addition, we do thorough language editing of the manuscript.

Reviewer comments:

Reviewer #1:

Manuscript Summary:

Accept

Response:

Thanks for your comments.

Reviewer #3:

The manuscript is likely to be of interest to investigators focused on DBS technology development. I have a few comments that should be addressed in a revised manuscript:

1). First, the manuscript could use some copy-editing as the manuscript has several typos in the introduction and discussion.

2). The table showing the supplies and materials appears to be disorganized and it is difficult to determine which product number is associated with each item. Some clarification could be made regarding the software used. Is the software open access or is it only available with a paid subscription?

3). I'm wondering if the authors could re-do the introduction to the video - there is some background noise (maybe a phone) that is somewhat distracting. In addition, the camera zooms in on the narrator during the introduction which is also distracting. Some additional polishing of this part of the video could be done in a revision.

Response:

1). First, the manuscript could use some copy-editing as the manuscript has several typos in the introduction and discussion.

Thanks, the typos have been corrected.

In line 12 of INTRODUCTION，the word “the” has been corrected to “a”;

In line 18 of INTRODUCTION，the word “individulised” has been corrected to “individualized”;

In line 20 of INTRODUCTION, the sentence “which are very important and necessary” has been deleted;

In line 21 of INTRODUCTION，the sentence “To address the above-methioned problems” has been corrected to “To address the problems mentioned above”;

In line 21 of INTRODUCTION，the word “the” has been corrected to “a”;

In line 23 of INTRODUCTION，the word “thus” has been deleted;

In line 13 of DISCUSSION，the word “preveiously” has been corrected to “previously”;

In line 29 of DISCUSSION，the word “Different” has been corrected to “being different”;

In line 41 of DISCUSSION，the sentence “may make more patients have the opportunity to receive” has been corrected to “may provide more patients with an opportunity to receive DBS surgery”;

In line 57 of DISCUSSION，the word “which” has been added to the sentence“can be placed for a long time without causing the phenomenon of mutual exclusion with the body”;

In line 62 of DISCUSSION，the word “sofeware” has been corrected to “software”;

In line 64 of DISCUSSION，the word “advocated” has been corrected to “encouraged”;

2). The table showing the supplies and materials appears to be disorganized and it is difficult to determine which product number is associated with each item. Some clarification could be made regarding the software used. Is the software open access or is it only available with a paid subscription?

We have rearranged the table. The software is only available with a paid subscription.

3). I'm wondering if the authors could re-do the introduction to the video - there is some background noise (maybe a phone) that is somewhat distracting. In addition, the camera zooms in on the narrator during the introduction which is also distracting. Some additional polishing of this part of the video could be done in a revision.

We have redone the introduction of the video.

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