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# Therapeutic Potential of 3D Printing Pen in Stroke Rehabilitation: Case Reports



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## Highlights

- A training program with the 3D printing pen might improve hand function in stroke patients.
- A training program with the 3D printing pen could improve visual-perceptual function in stroke patients.

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# Therapeutic Potential of 3D Printing Pen in Stroke Rehabilitation: Case Reports

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**Conflict of Interest**
The authors have no potential conflicts of interest to disclose.

## ABSTRACT

Medical applications for 3-dimensional (3D) printing are rapidly expanding and are expected to revolutionize health care. Two patients with chronic stroke participated in a training program with the 3D printing pen (3Doodler 2.0; WobbleWorks, Inc.). This training program consisted of 12 sessions for 4 weeks. The training program consisted of a 4-step protocol. In 2 patients with chronic stroke who showed impaired visuospatial function and hand function, each function improved without any serious adverse effects after completing training. This case study suggests the therapeutic potential of the 3D printing pen to improve visual-perceptual and hand functions in stroke patients.

**Keywords:** Printing, Three-Dimensional; Visuospatial Function; Hand Function; Stroke; Case Report

## INTRODUCTION

One well-accepted principle in stroke rehabilitation is task-specific training [1]. Under this principle, repetitive task training is an effective rehabilitation strategy to improve functional ability after stroke [2]. However, this conventional rehabilitation with repetitive task training might not interest some stroke patients due to a lack of motivation [3].

Medical applications for 3-dimensional (3D) printing are expanding rapidly and are expected to revolutionize health care [4]. The 3D printing pen can create art in 3D space with higher degrees of freedom. It may allow stroke patients to actively and interestingly approach the 3D space from the 2-dimensional (2D) plane. In addition, good hand motor skills are needed to successfully manipulate 3D printing pen. Application of the 3D printing pen in stroke rehabilitation could potentially improve visuospatial perception and hand function in patients with stroke. In this case study, we investigated the therapeutic potential of the 3D printing pen to improve visual-perceptual and hand fine motor functions in chronic stroke patients.

## CASE REPORT

### Training program with 3D printing pen

The 3D printing pen training program consisted of 12 sessions during 4 weeks (3 sessions per week). In each session, patients created a 3D drawing with the affected hand using the 3D printing pen (3Doodler 2.0; WobbleWorks, Inc., New York, NY, USA) for 30 minutes under the guidance of an occupational therapist (Fig. 1). The training program consisted of a 4-step protocol described as follows (Fig. 2):

Step 1. Drawing lines on the plane. In this step, patients drew objects such as triangles or pentagons using stencils from the website (http://the3doodler.com/projects/).

Step 2. Drawing lines in the 3D space. In this step, patients recognized a 3D structure on paper and then drew lines in 3D space to recreate the same 3D structures.

Step 3. Making structures by attaching 2D outputs. In this step, patients drew lines in separate planes using stencils and attached the planes to produce a complete 3D structure.

Step 4. Making structures by connecting 2D outputs with additional 3D drawing. In this step, patients drew lines using stencils and connected the plane lines to each other to produce a complete 3D structure with appropriate spatial configuration.

### Case 1

A 38-year-old man with intracranial hemorrhage in the right basal ganglia participated in a training program with the 3D printing pen (Fig. 3A). This patient with right-hander suffered an intracranial hemorrhage 6.5 years ago. He showed moderate impairments in visual-perceptual and left hand functions. However, his cognitive function was mild impairment with the Korean mini-mental state examination (K-MMSE) of 26, and there was no visual field defect on examination by an ophthalmologist. He performed the 3D printing pen training program for 4 weeks without any serious complications. He did not receive any occupational therapy for 4 weeks of the 3D printing pen training program. Each visual-perceptual and hand function were assessed with the Motor-Free Visual Perception-3 (MVPT-3) [5] and the box and block test (BBT) [6] before and after the program, respectively. In the BBT, the number of blocks per minute increased from 37 to 39 after the training program.

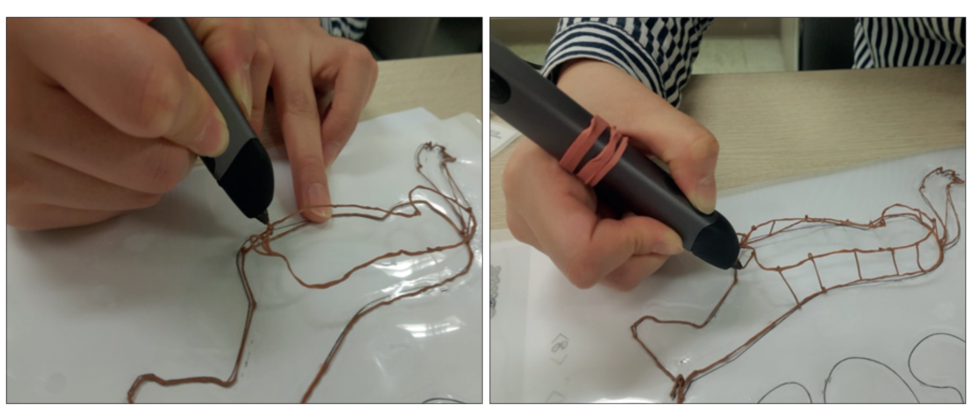

**Fig. 1.** Making structures with 3D printing pen by case 2.
3D, 3-dimensional.



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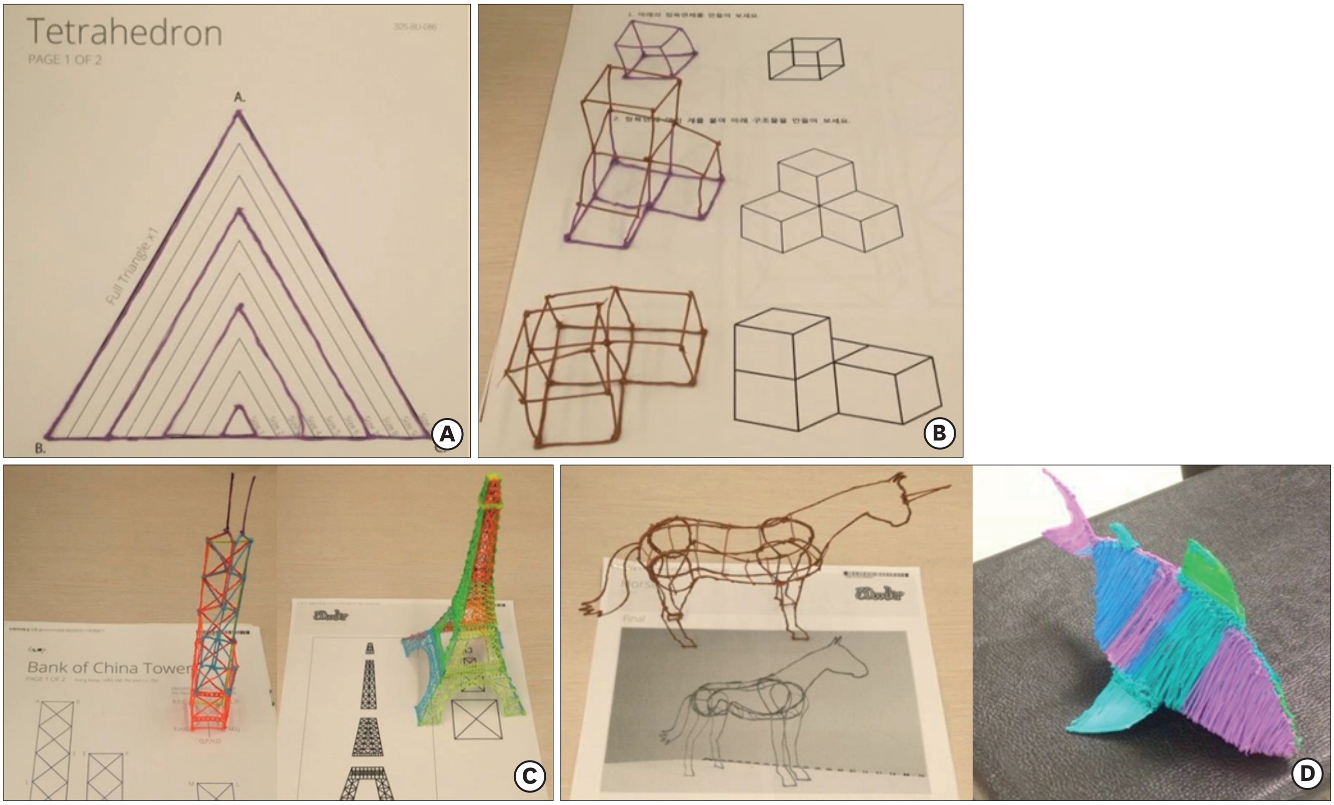


**Fig. 2.** Training program with the 3D printing pen. (A) Step 1: drawing lines on the plane. (B) Step 2: drawing lines in the 3D space. (C) Step 3: making structures by attaching 2D outputs. (D) Step 4: making structures by connecting 2D outputs with additional 3D drawing.
2D, 2-dimensional; 3D, 3-dimensional.

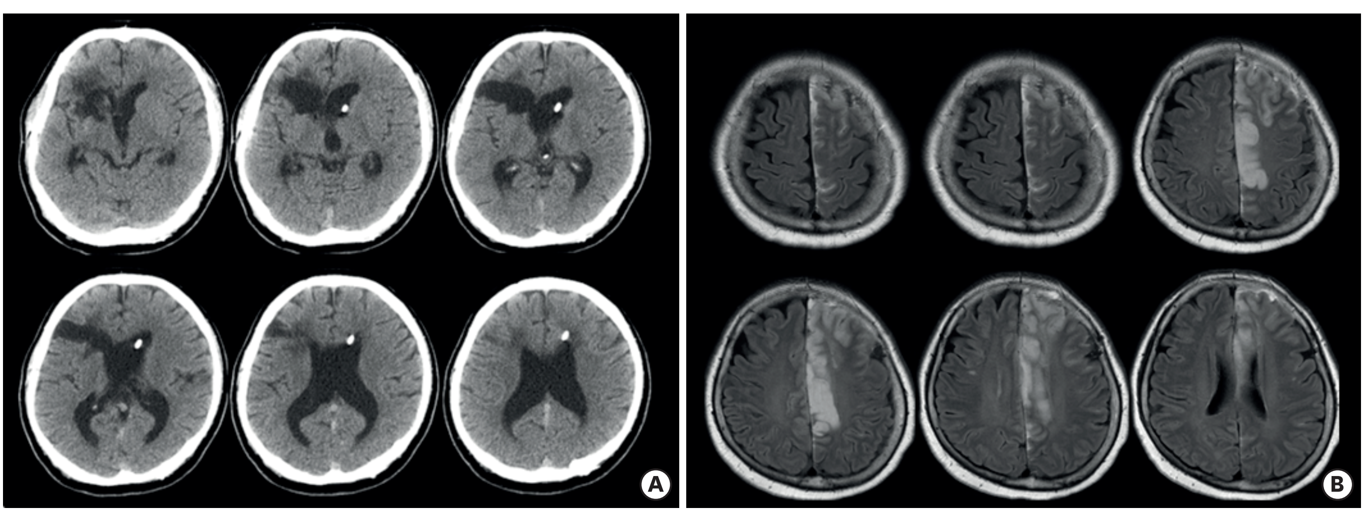


**Fig. 3.** Brain images of 2 stroke patients. (A) Brain CT of case 1. (B) Brain MRI of case 2.
CT, computed tomography; MRI, magnetic resonance imaging.

In the MVPT-3, the visual memory score increased from 8 to 10, and visual closure score increased from 11 to 12 after the training program. Additionally, the time required for MVPT-3 decreased from 52 to 22 minutes after the training program. The patient rated moderate satisfaction for this training program.


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### Case 2

A 55-year-old woman with left anterior cerebral artery infarction participated in the training program with the 3D printing pen (Fig. 3B). The duration of stroke was 6 months. This patient with right-hander showed mild impairments in right hand function. Her cognitive function was no impairment with the K-MMSE of 30. A lack of motivation for conventional hand motor rehabilitation was a main problem to her. She performed the 3D printing pen training program for 4 weeks without any serious complications. She did not receive any occupational therapy for 4 weeks of the 3D printing pen training program. Her hand function was assessed with BBT and Jebsen-Talyor hand function test (JTHFT) [7] before and after the training program. In the BBT, the number of blocks per minute increased from 42 to 45 after the training program. In addition, the time required decreased from 3.62 to 2.92 seconds for turning cards, from 5.64 to 5.18 seconds for small objects, and from 4.31 to 3.12 seconds for light cans in JTHFT. The patient also reported moderate satisfaction with the training program.

## DISCUSSION

In the medical profession, 3D printing is mainly used in medical modeling and surgical planning. The advantages of 3D printing include customizability, onsite production, and ability to produce complex shapes [8]. In addition, 3D printing pen with a 3D printing technique can create 3D objects through successive deposition of material. This 3D printing technique has the potential to produce 3D materials with a self-directed method. The conventional rehabilitation therapy to improve function has been applied to stroke patients at high intensity and high frequency over a long period based on the positive dose-response relationship [9]. However, intensive rehabilitation therapy is often limited by a lack of motivation in stroke patients. Self-directed rehabilitation could be an important rehabilitation strategy to improve the motivation of stroke patients. In this aspect, 3D printing pen with a relative inexpensiveness could be an additional tool in stroke rehabilitation.

Many rehabilitation approaches have been reported to improve hand motor function in stroke patients. The most beneficial interventions in improving hand motor function are known as constraint-induced movement therapy and robot-assisted training, which are based on correct, active, repetitive exercise [1]. However, stroke patients might not comply with these conventional rehabilitation interventions. Therefore, one important issue to address is how to maintain compliance with correct, active, repetitive exercise for successful rehabilitation to improve hand motor function. In this respect, the 3D printing pen might be a new tool for rehabilitation to improve hand motor function because patients can actively operate the 3D printing pen by themselves with higher degrees of freedom. In this study, both case 1 and 2 improved hand motor functions with a moderate level of satisfaction after training for 4 weeks. These results might suggest that the 3D printing pen training program would be helpful for stroke patients with a lack of motivation for conventional rehabilitation to improve hand motor function.

In case 1 with stroke duration of 6.5 years, visual-perceptual function showed a definite improvement after undergoing the 3D printing pen training program for 4 weeks. In particular, the time required for MVPT-3 significantly decreased after the training program. The MVPT-3 is easily conducted within 20–30 minutes in people aged 4–95 years [5,10]. This patient performed the MVPT-3 in 52 minutes before the 3D printing pen training program,


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which is 2 times longer than in the normal population. After participating in the training program for 4 weeks, he performed the MVPT-3 in a similar time as the normal population. This decrease in time required for MVPT-3 is evidence of improved visual-perceptual function. Although the patient had received conventional rehabilitation therapy for more than 2 months before this training program, he showed no definite improvement in visual-perceptual function. Rehabilitation approaches to improve the visual-perceptual function in stroke patients include visual scanning training, phasic alerting, cueing, and imagery [11]. Among these approaches, visual scanning training is most strongly recommended to improve visual-perceptual function [12]. Visual scanning training is more active than other training approaches. The 3D printing pen could allow such patients to actively create 3D tools to improve visual-perceptual function. The advantages of 3D printing pens might be significantly greater than those of conventional rehabilitation approaches.

This study could not assess the long-term effect of a training program with the 3D printing pen. In addition, there was no control case or no comparison with virtual or augmented reality program using 3D environment case in this study. A case-control study with a large number of patients is needed to clarify the therapeutic effect of the 3D printing pen training program in stroke rehabilitation. Despite these limitations, this case study suggests the therapeutic potential of the 3D printing pen to improve visual-perceptual function and hand function in chronic stroke patients.

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