ORIGINAL ARTICLE

# CT advantages of potential use of polymer plastic clips in neurocranium

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## ABSTRACT

**Aim** Clips in neurosurgery are made of titanium alloys, which reduce artifacts on computed tomography (CT). The radiological advantage of plastic clips on the CT image was demonstrated when they were placed in an inter-hemispherical position at an angle of 90º. The aim of this study was to investigate the behaviour of the clip placed at different angles.

**Methods** Sixty heads of domestic pigs were divided into two groups, in group 1 a titanium clip was placed to the interhemispheric position at an angle of 90º, 45º, 0º, ten heads for each angle. In group 2 a plastic clip was placed in the same way. CT scan of the brain was performed for each angle. The size of the density and possible artifact were measured on CT.

**Results** The size of the titanium clip ranged from 17.05 mm at an angle of 0º in the axial plane to 91.47 mm at an angle of 0º in the sagittal plane. The average size of the plastic clip ranged from 6.4 mm at an angle of 0º in the axial plane to 23.22 mm in an angle of 90º in the sagittal plane. Artifacts were observed only in the titanium clip.

**Conclusion** Plastic clips have shown radiological advantages over titanium clips in the CT image. The average density size of the plastic clip in all planes and all angles was smaller than the titanium clip.

**Key words:** aneurysm clipping, artifacts, computed tomography

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## INTRODUCTION

Neurosurgical treatment of intracranial aneurysms with permanent closure using "spring clips" placed above the neck of the aneurysm was introduced more than forty years ago, and has become the standard procedure (1). But researchers have observed significant artifacts around the clips, which can cover contrast about them. Although the fourth generation of clips in neurosurgery is made of titanium and its alloys, in order to reduce artifacts on computed tomography (CT) and magnetic resonance (MR) scan (2), they continue to interfere with image interpretation.

However, artifacts usually depend on physical properties of the material from which the clips are made. The physical properties of plastic materials, their lower atomic number and density (3), make them attractive for use in CT. Plastic clips are a diamagnetic material (4) and cause fewer artifacts than titanium clips, which are standard in neurosurgery.

The radiological advantage of plastic clips was shown in CT imaging when placed in the frontobasal, interhemispheric position at a 90º angle, in an animal model (5), however, the advantages and possible artifacts at different angles and different planes are unknown.

Bearing in mind that polymer plastic clips are increasingly used in endoscopic surgery, our study intends to examine the CT characteristics of plastic clips at different angles, after application to the pig neurocranium, and compare it with standard titanium clips.

## MATERIALS AND METHODS

### Materials and study design

This prospective clinical study was performed at the Department of Surgery, Veterinary Faculty, University of Sarajevo, and in the Clinic for Radiology and Nuclear Medicine, University Clinical Centre Tuzla during 2020.

The experimental part of the study, craniotomy and placing of clips, was performed at the Veterinary Faculty, University of Sarajevo, Department of Surgery, and CT and MRI were performed in the University Clinical Centre (UKC) Tuzla, Clinic for Radiology and Nuclear Medicine. The Ethical Committee of the UKC Tuzla approved this research (No:02-09/2-63-13). Treatment of animals was in accordance with the principles of the Declaration of Helsinki.

### Methods

Sixty heads of domestic pigs (*Sus scrofa domestica*) with white hair, "Danish Landras", were taken in this study. Inclusion criteria were healthy adults, with no head or brain damage during the sacrifice. Excluding criteria were immature young animals, as well as diseased ones and specimens where head and brain damage occurred during sacrifice. The animals were divided into two groups; group I in which a permanent titanium clip was placed in the neurocranium - at an angle of 90º, 45º and 0º, 10 heads for each angle, and group II in which a plastic polymer clip was placed in the neurocranium - at an angle of 90º, 45º and 0º, 10 heads for each angle.

**Operative procedure.** A craniotomy was performed on the head of a domestic pig. After an arcuate incision from the right to the left orbital arch, the subcutaneous tissue and muscles of the frontal region were dissected and denuded from the bone. The temporalis muscle was removed, and in this region the trepanation was opened with a drill and then connected with a Gili saw, thus performing a craniotomy. The intact dura was incised with a scalpel, and the accesses to the brain was obtained.

In the first group of animals, the permanent Yasargil FT 746 T clip (external size 15.2 mm, length of clip leg 8.1 mm, weight 0.2 g) was placed in the frontobasal, interhemispheric position, at an angle of 90º, 45º and 0º.

In the second group of animals, the polymer Hem-o-lok clip ML (external size 9.3 mm, weight 0.05 g) was placed in the same position at an angle of 90º, 45º and 0º.

**CT scan.** After the operative procedure, a brain CT scan was performed using a 64-slice CT (Siemens Somatom Sensation, Erlangen, Germany) (mAs 380, 120 KW, slice 5.0 mm, delay 4 sec., scan time 12.18 sec., 59.43 mGrey). Scans were performed in the axial, sagittal, and coronal planes, a brain window W:80, L:40.

**Parameters of monitoring.** The density expressed in Hounsfield units (HUI) was monitored on axial CT sections through the placement site of the titanium and plastic clips and its size expressed in mm was measured. If artifacts are observed, the measure of their size is expressed in mm.

We analysed CT images taken after the titanium and plastic clip placement at 90º, 45º, and 0º, in the soft tissue window and the brain window, in the axial, sagittal, and coronal cross-sections.

The artefacts seen in the CT brain window in axial, sagittal, and coronal cross-sections were then analysed.

### Statistical analysis

Results are expressed as mean values with standard deviation. The statistical significance of the differences was tested by the Kolmogorov-Smirnov test. The difference at the level of $p<0.05$ was considered statistically significant. Statistical analysis was performed in the Statistica 10.0 program for the Windows application.

## RESULTS

The densities of the plastic and titanium clips were measured on each CT scan. If we look at the average size of the plastic and titanium clips at different angles on the CT scan (Table 1), we can observe that it ranged from 6.4 mm at an angle of 0º in the axial plane to 23.22 mm at an angle of 90º in the sagittal plane. The size of the titanium clip ranged from at least 17.05 mm at an angle of 0º in the axial plane to 91.47 mm in the sagittal plane at an angle of 0º.

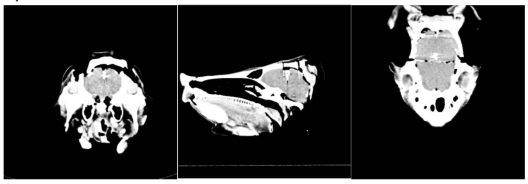
**Table 1. Average size of plastic and titanium clip at an angle of 0º, 45º and 90º on CT scans in the soft tissue window (MT) and brain window (MP)**

| Clips | Angle=0° | | Angle =45° | | Angle =90° | |
|---|---|---|---|---|---|---|
| | Plastic clip | Titanium clip | Plastic clip | Titanium clip | Plastic clip | Titanium clip |
| MT_CT_sag | 16.853 | 72.541 | 12.709 | 67.649 | 14.688 | 63.939 |
| MT_CT_ax | 6.414 | 17.048 | 7.537 | 20.243 | 12.052 | 51.101 |
| MT_CT_kor | 12.131 | 35.948 | 9.956 | 39.780 | 5.016 | 20.062 |
| MP_CT_sag | 22.868 | 91.469 | 22.812 | 85.380 | 23.222 | 73.080 |
| MP_CT_ax | 10.727 | 28.936 | 13.647 | 35.390 | 17.930 | 85.162 |
| MP_CT_kor | 21.371 | 46.799 | 16.733 | 51.626 | 11.999 | 31.124 |

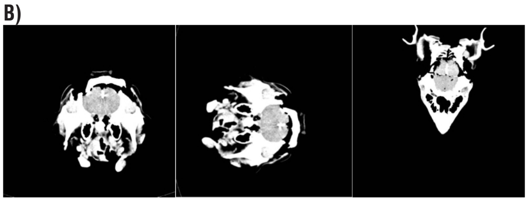
To test the difference between the sizes of the titanium and plastic clips at an angle of 90º, 45º and 0º, i.e. at which angle was the largest and the smallest, respectively, in the sagittal, axial, coronal plane (including all angles and all planes), we used Kolmogorov - Smirnov test.

There was a statistically significant difference in the distributions of the MP_CT variable between the plastic and titanium clips ($p <0.001$). The same is true of all the other variables tested for which a difference was found (Figure 1, 2).

**A)**



**B)**



**C)**

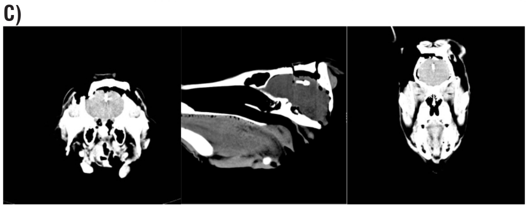
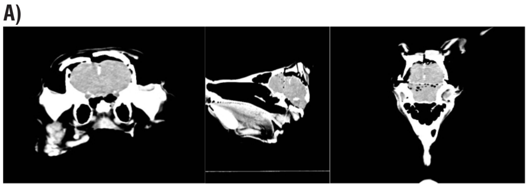
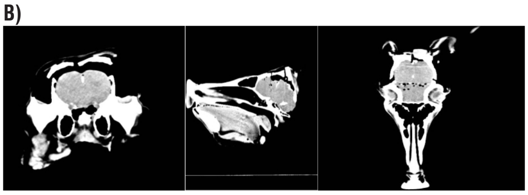


**Figure 1. CT of a titanium clip, the brain window, sagittal (left), coronal (middle), and axial cross-sections (right) at A) 90°, B) 45° and C) 0°** (Delibegović M, 2020)

**A)**



**B)**



**C)**

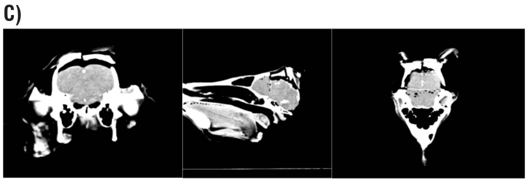


**Figure 2. CT of a plastic clip, the brain window, sagittal (left), coronal (middle), and axial cross-sections (right) at A) 90°, B) 45° and C) 0°** (Delibegović M, 2020)

It was observed that the size of the artifacts was the smallest at the angle of 45° in all three sections (Table 2, Figure 3).

**Table 2. Size of artifact at angles 0°, 45° and 90° in all three cross-sections**

| Angle | Axial cross-sections | Sagittal cross-sections | Coronal cross-sections |
|---|---|---|---|
| 0° | 15.5±3.6 x 1.8±0.4 | 7.5±3.8 x 0.8±0.5 | 7.5±3.8 x 0,8±0.5 |
| 45° | 8.8±0.6 x 1.6±0.6 | 6.3±3.7 x 1.1±0.5 | 6.3±3.7 x 1,1±0.5 |
| 0° | 10.8±4.7 x 1.4±0. | 13.6±0.6 x 1.5±0.5 | 13.6±0.6 x 1.5±0.5 |


**Figure 3. Artifacts seen in the CT of a titanium clip, the brain window, sagittal (left), coronal (middle), and axial cross-sections (right) at A) 90°, B) 45° and C) 0°** (Delibegović M, 2020)

## DISCUSSION

The CT and MR compatibility of neurosurgical clips is an essential requirement. Metallurgical and physical tests of clips have proven MR compatibility of clips made of non-ferromagnetic materials. However, these investigations have revealed significant artifacts around the clips, which may cover the contrast in their vicinity (6-9).

Artifacts are structures in the image that do not correspond to the spatial distribution of tissues in the plane of the image. To avoid diagnostic misinterpretation, it is recommended to learn how to detect artifacts. However, artifacts usually depend on the physical properties of the material from which the clips are made (10). The latest generation of clips in neurosurgery is made of titanium and its alloys, which reduces artifacts on CT and MR scans (1).

Metal implants in patients' bodies cause strong, striped artifacts that will overshadow or make crucial information less clear and reduce image quality. The academic community believes that the explanation for this phenomenon is beam homogenization (11,12).

In addition to the attempts to reduce artifacts by changing the composition of the materials used to make the clips, imaging techniques have been developed to reduce artifacts (13).

The causes of metal artifacts are quite complicated. Depending on the shape and density of metal objects, the appearance of artifacts can be significant (14). Metal objects can cause beam homogenization, partial volume, aliasing, under-range in electronic data acquisition, or dynamic range overflow in the reconstruction process (15).

When the cause of metal artifacts is dominated by air beam homogenization, artifacts can be corrected algorithmically, and various algorithms are presented (16-21). So far, no effective and affordable scheme for the correction of metal artifacts has been found. Often, the correction of metal artifacts is complicated by the movement of the patient, which creates additional projection inconsistency and worsens striped artifacts. An additional area next to the metal object was also destroyed (22). For many clinical applications, the interface between the implant and adjacent bone and soft tissue is of great interest to the clinician (23).

The use of Hem-o-lock clips, which are non-resorptive, polymeric structures, for ligation of blood vessels, ureters, bile ducts, and appendix bases, has been documented in more than 1,000 surgical procedures (24-26). However, there are no reports of their use in neurosurgery, although plastic clips have some potential benefits.

The physical properties of plastic materials, their lower atomic number and density (2), make them attractive for the use in CT. The radiological advantage of plastic clips has been shown when placed in the frontobasal, interhemispheric position at an angle of 90 º, in an animal model (5). However, it is not known what the advantages and possible artifacts are at different angles and in different planes.

Our study showed that the average shadow size of the plastic clip in CT soft tissues (MT) and brain window (MP) in the sagittal, axial and coronary planes, and at an angle of 0º, 45º and 90º was smaller compared to the titanium clip.

The orientation of the clips significantly affects the size of the artifact. Artifacts are worst with a clip in an aneurysm at an angle of 45º and 90º, on 3D CT and DS angiography (27). The smallest artifacts can be expected when the longer axis of the clip is perpendicular to the longer axis of the wrinkle scanner and therefore in the plane of the cut (28).

Titanium clips, well documented, reduce artifacts observed relative to ferromagnetic clips. However, some shortcomings remain due to metallic characteristics such as a large part of the spring, and production difficulties (29).

Clip artifacts can also affect the quality of three-dimensional CT angiography, which is used as a diagnostic method in postoperative evaluation after aneurysm clipping. The expression and distribution of these artifacts depend on the clip-stand angle and the plane of the image reconstruction (30). Most neurosurgeons would agree that it is ideal for patients with aneurysms, ruptured and non-ruptured, to undergo imaging follow-up after placement of a permanent clip. This approach is justified by the importance of determining whether a parent vessel has stenosis or if there is a residual neck aneurysm. The need for an immediate postoperative angiogram and another one after three years was emphasized (31). However, the present artifacts interfere with the interpretation of the image.

In conclusion, plastic clips have shown radiological advantages over standard titanium clips in the computed tomography images. The average density size of the plastic clips in all planes and all angles were smaller than the titanium clips, and they do not cause artefacts. Neuroradiologists and neurosurgeons should be aware of the CT advantage of plastic clips. Before their use in human medicine, further studies of the aneurysmal model are needed.

## FUNDING

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## TRANSPARENCY DECLARATION

Competing interests: None to declare.

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