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# Comparison of Sternum Approximation Stability Using Stainless Steel Wire with Polydioxanone (PDS)

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**ABSTRACT**

**Background:** The median sternal incision is an incision that is commonly done in heart surgery and vascular surgery. The existing techniques need elaboration and innovation to produce a method with an optimal level of healing effectiveness accompanied by a minimal risk of side effects. This study aims to determine the difference between sternal approximation using stainless steel wire compared to polydioxanone (PDS) based on biomechanical analysis. **Methods:** This was an in vitro experimental study using the sternum of a goat. A total of 24 sternums were divided into 6 treatment groups. Data analysis was performed with SPSS version 20. Univariate and bivariate analyzes were performed to compare the sternal approximation between stainless steel wire and PDS. **Results:** The use of PDS showed a higher average increase in transverse and longitudinal approximations compared to the use of stainless steel wire and was statistically different, $p<0.05$. PDS does not differ from stainless steel wire in lateral approximation. **Conclusion:** Stainless steel wire is more optimal in maintaining sternal stability than PDS based on biomechanical tests.

## 1. Introduction

The median sternal incision is an incision that is commonly done in cardiac surgery and vascular surgery. This technique has been used for a long time, but it is not without risk. Several studies have noted that there is a possibility of sternal dehiscence or mediastinal infection after surgery of around 0.8-1.5%. The risk of developing sternal dehiscence or mediastinal infection can increase up to 2.4% after bilateral internal mammary artery grafting. Some studies show that around 34.5% of patients experience impaired sternal healing at 3-6 months after surgery. The high rate of impaired sternal healing indicates that the existing techniques need elaboration and innovation to produce a method with an optimal level of healing effectiveness accompanied by a minimal risk of side effects.[1-6]

For decades, stainless steel wire was used to fix the sternal incision. The use of stainless steel wire is the main choice because it is effective, easy, cheap, and safe. Several other materials used for sewing also vary, such as steel bands, polydioxanone, nylon, and custom-made-titanium H-plate. The use of stainless steel wire and PDS is the standard sternal approximation technique. Each technique is stated to be able to maximize the stability of the sternum.[7-11] Therefore, this study aims to determine the difference between sternal approximation using stainless steel wire compared to polydioxanone (PDS) based on biomechanical analysis.

## 2. Methods

This study was an in vitro experimental study with a post-test approach with a control group. The study sample used the sternum of a Goat (*Carpa hircus*). A total of 24 sternal heads from male goats weighing 27-30 kg and aged 18-24 months were used in this study. Furthermore, the test samples were grouped into six groups, namely group 1: a transverse strain test was carried out at the approximation of the sternum using a stainless steel wire; group 2: a longitudinal strain test was performed at the approximation of the sternum using a stainless steel wire; group 3: a lateral tension test was performed at the approximation of the sternum using a stainless steel wire; group 4: a transverse stretch test was performed at the approximation of the sternum using PDS; group 5: a longitudinal strain test was performed on the approximation of the sternum using PDS; group 6: a lateral tension test was performed at the approximation of the sternum using the PDS. This study was approved by the medical and health research ethics committee of the Faculty of Medicine, Universitas Sriwijaya.

The sternotomy process is carried out using a saw. Next, an approximation of the sternum was performed using 6 metric stainless steel wire. Then the sternal gap was measured transversely, longitudinally, and laterally with a feeler gauge. Then, a plate was installed on each side of the sternum, which was fixed with a 4 mm screw. On the approximated and fixed sternum, the operator is loaded longitudinally, transversely, and laterally with loads of 100 N, 160 N, 220 N, 300 N, and 400 N, respectively, for 5 seconds using the servo-hydraulic autograph Shimadzu AG-10 TE machine and measuring the separation or displacement of the sternal bones at each load using a peeler gauge.

Data processing and analysis will be done with SPSS 20.0 for Windows software. Univariate analysis was performed to present the distribution of data frequencies between treatment groups. Bivariate analysis was carried out to determine the average difference between treatments with the Independent T-Test with a $p<0.05$ value.

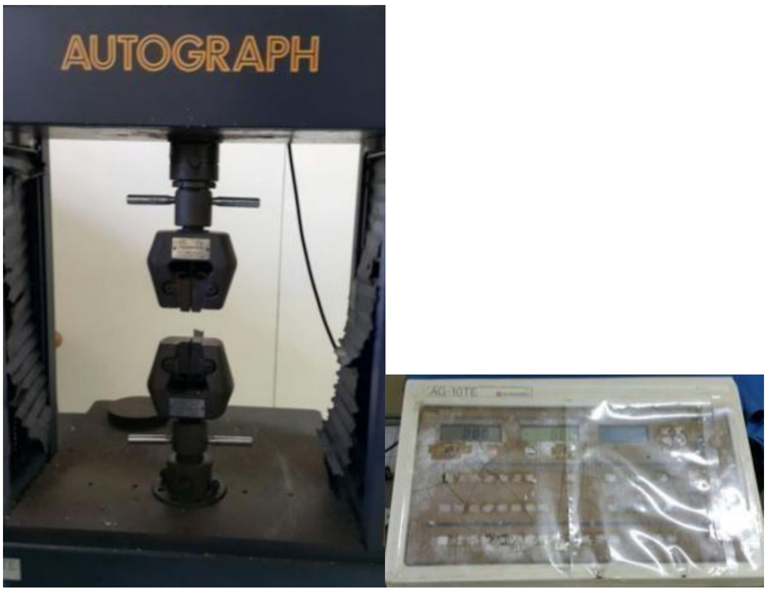


Figure 1. Servo-hydraulic autograph Shimadzu AG-10 TE machine.

## 3. Results

Table 1 shows a comparison of the transverse approximation between stainless steel wire and PDS. The use of PDS showed an increase in the average transverse approximation, which was higher than the use of stainless steel wire and was statistically different, $p<0.05$. The approximation average of the PDS transverse is consistently much higher than the use of stainless steel wire at all load levels.

Table 1. Comparison of the transverse approximation between stainless steel wire and PDS.

| **Load (Newton)** | **Stainless steel wire (mm)** | **PDS (mm)** | **p-value*** |
|---|---|---|---|
| 100 N | 0.06±0.01 | 0.12±0.15 | 0.001 |
| 160 N | 0.15±0.02 | 0.71±0.03 | 0.001 |
| 220 N | 0.48±0.03 | 1.30±0.09 | 0.001 |
| 300 N | 0.99±0.06 | 1.86±0.09 | 0.001 |
| 400 N | 1.14±0.04 | 2.41±0.40 | 0.001 |

*Independent T-test, $p<0.05$.

Table 2 shows the comparison of the longitudinal approximations between stainless steel wire and PDS. The use of PDS showed a higher mean longitudinal approximation than the use of stainless steel wire and was statistically different, $p<0.05$. PDS longitudinal approximation average is consistently much higher than the use of stainless steel wire at all load levels.

Table 2. Comparison of the longitudinal approximation between stainless steel wire and PDS.

| **Load (Newton)** | **Stainless steel wire (mm)** | **PDS (mm)** | **p-value*** |
|---|---|---|---|
| 100 N | 2.01±0.47 | 4.50±1.49 | 0.020 |
| 160 N | 5.97±0.57 | 7.35±0.96 | 0.019 |
| 220 N | 8.80±1.47 | 12.48±1.45 | 0.006 |
| 300 N | 10.64±0.94 | 14.40±1.79 | 0.007 |
| 400 N | 14.64±2.34 | 17.90±0.69 | 0.030 |

*Independent T-test, $p<0.05$.

Table 3 shows the comparison of lateral approximations between stainless steel wire and PDS. The use of PDS showed relatively the same average lateral approximation in the use of stainless steel wire and was not statistically different, $p>0.05$. The average PDS lateral approximation is consistently the same compared to the use of stainless steel wire at all load levels.

Table 3. Comparison of lateral approximation between stainless steel wire and PDS.

| **Load (Newton)** | **Stainless steel wire (mm)** | **PDS (mm)** | **p-value*** |
|---|---|---|---|
| 100 N | 0.42±0.03 | 0.40±0.05 | 0.636 |
| 160 N | 0.83±0.13 | 0.80±0.15 | 0.758 |
| 220 N | 1.41±0.15 | 1.37±0.16 | 0.739 |
| 300 N | 2.14±0.14 | 2.01±0.03 | 0.113 |
| 400 N | 3.24±0.19 | 3.23±0.33 | 0.970 |

*Independent T-test, $p<0.05$.

## 4. Discussion

Sternum separation at approximation with stainless steel wire does not exceed 2mm at a maximum loading of 400 N (1.14 ± 0.04 mm). In contrast to the approximation with PDS at 400 N loading, a separation of more than 2mm (2.41 ± 0.40 mm) occurs. These results are different from the results of the study, which stated that the minimum force on the anteroposterior (transverse) aspect for disruption of the sternum was 263 N, whereas, in this study, the approximation with PDS experienced a separation of more than 2mm at 400 N loading, whereas in the approximation with stainless steel wire rust was not found a shift of more than 2mm even though given a maximum load (400 N). Stability at 400 N loading is very important because this is the physiological force that the sternum receives when coughing, and post-sternotomy patients will be trained to cough in order to restore breathing effectiveness. In the longitudinal strain test, there is a significant difference at all loads ($p < 0.05$), and separation of more than 2mm occurs in both techniques at an initial loading of 100 N. This difference is also seen in the results of the longitudinal strain test, where the minimum force required for disruption occurs at 325 N, whereas in this study, the separation of the sternum of more than 2mm occurred when loading at 100 N. A considerable shift of the sternum was found in this longitudinal strain test because the sternum was not fixed by the surrounding tissue. As we know, this longitudinal stretch arises due to the lateral pull of the pectoralis major muscle, where mobilization of one side of the sternum can occur cranio-caudal if one of the two rectus abdominis muscles is detached from the sternum.[13-16]

The results of the transverse and longitudinal strain tests showed that the approximation with stainless steel wire was less shifted than the approximation with PDS. In approximation with stainless steel wire, the suture is oblique and horizontal at an angle of about 45 degrees so that strain forces are distributed, and dehiscence is rare. In the lateral tension test, there is no significant difference at all loads between the approximations with stainless steel wire and PDS, but when viewed from the average value of the shifts that occur, it is found that the approximations with PDS experience less displacement than the approximations with stainless steel wire. In the lateral pull, there is a separation of the sternum of more than 2mm in both techniques with a loading of 300 N. These results are different from studies that state that the minimal force to cause disruption occurs when the loading is 220 N. In cranio-caudal (longitudinal) and anterior-posterior (transverse), the approximation technique with stainless steel wire is better and statistically has a significant difference compared to the approximation with PDS. However, in terms of lateral tension, the approximation with PDS statistically does not have a significant difference compared to the approximation with stainless steel wire. These results are not in line with the results of studies that prove that an approximation with stainless steel wire is as effective as an approximation with PDS in preventing sternal dehiscence.[17-21]

## 5. Conclusion

Stainless steel wire is more optimal in maintaining sternal stability than PDS based on biomechanical tests.

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