Comparison of Electrosurgical Vessel Sealing Devices Using Digital Image Correlation

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Introduction

Electrosurgical vessel sealing devices are used in a variety of surgical procedures and have been demonstrated to reduce operative time and patient blood loss[1]. Such devices work by applying pressure and passing a high frequency alternating current through the tissue. This results in an increase in tissue temperature, causing the collagen within the blood vessel wall to denature forming a gel-like substance acting as glue between the vessel walls[2, 3]. One aspect of the design known to affect the performance of such devices is the surface structure of the shims. The shims are the part of the device contacting with the tissue and delivering the current. Existing work investigating this area is limited to comparing structured shims against smooth shims in terms of the number of seal fails and a qualitative assessment of seal sticking. When comparing the two types of shims, structured surfaces provided a lower seal failure rate but more pronounced adhesion [4]. Furthermore, smooth surfaces have been shown to have a higher peak temperature during sealing [5]. This study aimed to develop a number of shims with varying surface structures to quantify the effect of different features on the sealing process.

Materials and Method

Porcine carotid arteries were obtained from an abattoir; vessels were frozen on the day of slaughter and defrosted on the day of testing. Vessels were skeletonised and sectioned using surgical scissors. The position from the bifurcation was measured, along with the outer vessel diameter and wall thickness. All measurements were conducted using digital Vernier calipers and repeated three times. The vessel was then sealed using the PlasmaKinetic OpenSeal device (with standard and modified shims) connected to a G400 generator.

Burst Pressure and Adhesion Testing

Vessels were cut into 30mm sections, with the seal located at the center of each section. Following the sealing process the vessel was removed from the device using a handheld force gauge (Mecmesin) to perform a peel test, with peak peeling force recorded. The vessel was then connected to perfusion apparatus consisting of a syringe pump and digital pressure indicator (Druck). A blunt needle was attached to the syringe and the vessel was attached using a haemostat. The vessel was then infused with physiological saline (10% w/v) at a rate of 50 ml/hr until the seal failed with the maximum pressure recorded.

Digital Image Correlation (DIC)

Vessels were sectioned into 40mm segments, and sealed at one end using the device. The vessel was attached to the perfusion apparatus as described previously and pressurised to ≈60mmHg before being clamped by the device. A speckle pattern was applied using black and white face paints. The vessel was sealed with the process being captured using the DIC system. A camera set-up consisting of two digital cameras (Limess) was established prior to testing with data being collected and analysed using the Q-400 DIC system (DANTEC Dynamics). The seal was then burst pressure tested.

Results and Discussion

Seven pairs of shims were modified for use with the PlasmaKinetic OpenSeal device, with one unmodified pair tested. There was a significant difference when comparing seal area between the different shims (p<0.001). In general the shims with grooves produced a smaller seal area than shims without. Data collected using DIC shows significant displacement occurring across the surface of the vessel. A rapid contraction occurs due to the pulsed waveform, pulling the vessel towards the sealing device. Figure 1 shows a sequence of images showing the sealing process captured using a conventional camera. With the increase of tissue temperature water within the vessel wall turns to steam causing an increase in pressure. The fold produced is thought to be as a result of this pressure build up.

Figure 1. Images taken using a conventional camera during the electrosurgical sealing process.
A total of 168 seals were performed for testing burst pressure and adhesion, with results summarized in Table 1. The Kruskal-Wallis test was performed to test for differences between groups with significant differences found for both burst pressure (p<0.001) and peel strength (p<0.001). The 45° grooved shim has a significantly lower burst pressure than all other shims. No shim performed significantly better than the original shim although the combination pair produced a lower seal failure rate and a higher mean burst pressure. A seal failure was defined as burst pressure <360mmHg. Results suggest that groove orientation is the most influential factor affecting the performance of the device. When considering peel strength, no shim pair offered a significant improvement compared to the original shim.

Table 1. Summary of shim details and shim results, with a burst pressure <360mmHg considered a seal failure and data presented as mean±SD.

<table>
<thead>
<tr>
<th>Shim Name</th>
<th>Description</th>
<th>Burst Pressure (mmHg)</th>
<th>Seal Failure Rate</th>
<th>Peel Strength (N/mm)</th>
<th>Seal Area (mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Original *n=20</td>
<td>Unmodified original shim</td>
<td>585.45 ±261.77</td>
<td>5.0%</td>
<td>0.088 ±0.037</td>
<td>18.35 ±2.51</td>
</tr>
<tr>
<td>Smooth n=22</td>
<td>Rough surface coating removed</td>
<td>468.77 ±192.80</td>
<td>27.3%</td>
<td>0.120 ±0.073</td>
<td>16.34 ±3.96</td>
</tr>
<tr>
<td>Normal Grooved n=21</td>
<td>Smooth shim with transverse grooves</td>
<td>547.05 ±266.24</td>
<td>14.3%</td>
<td>0.096 ±0.042</td>
<td>16.64 ±2.99</td>
</tr>
<tr>
<td>Narrow Grooved n=21</td>
<td>Smooth shim with narrow transverse grooves</td>
<td>507.00 ±209.07</td>
<td>33.3%</td>
<td>0.074 ±0.039</td>
<td>14.79 ±3.37</td>
</tr>
<tr>
<td>HF Grooved n=21</td>
<td>Smooth shim with high frequency transverse grooves</td>
<td>606.33 ±238.74</td>
<td>14.3%</td>
<td>0.084 ±0.042</td>
<td>14.89 ±2.61</td>
</tr>
<tr>
<td>Long Grooved n=20</td>
<td>Smooth shim with longitudinal grooves</td>
<td>549.85 ±253.22</td>
<td>25.0%</td>
<td>0.164 ±0.053</td>
<td>14.62 ±4.78</td>
</tr>
<tr>
<td>45 Degree Grooved n=19</td>
<td>Smooth shim with 45° grooves</td>
<td>191.05 ±113.17</td>
<td>89.5%</td>
<td>0.063 ±0.038</td>
<td>16.07 ±3.32</td>
</tr>
<tr>
<td>Combination n=24</td>
<td>A combination of the long grooved and normal grooved</td>
<td>764.46 ±388.331</td>
<td>0.0%</td>
<td>0.111 ±0.070</td>
<td>12.80 ±3.26</td>
</tr>
</tbody>
</table>

*n= number of tests

Conclusion
Shim surface profile significantly affected the performance of the device with the addition of grooves producing a smaller seal area. No significant improvement was found in device performance when considering burst pressure and adhesion, although results suggest groove orientation was the most influential factor affecting the quality of the seal produced.

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References