Ex-vivo Comparison of Efficiencies of LOTUS® and Ethicon® Ultrasonic Instruments

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Introduction

Tissue brought into contact with a metal rod (waveguide) resonating in a harmonic vibration mode above 20kHz is able to absorb energy as a result of 4 processes. These are, in decreasing order of effectiveness; compression force, fluid cavitation, surface friction and shear force. Through these processes controlled haemostatic cutting of tissues is possible by Ultrasonic Cutting and Coagulation Devices (UCCDs), e.g. the Ethicon Harmonic Scalpel®.

The waveguide of such a device provides a means of storing vibration energy in a long rod running from an electrical transducer input end to the tissue output end. A travelling wave induced in the waveguide transfers energy down the waveguide and into the tissue.

A waveguide can be made to vibrate in three different modes; longitudinal, transverse or torsional. The Ethicon Harmonic Scalpel® vibrates in a longitudinal mode; the distal end moves like a piston back and forth, generating high levels of compression force at the instrument – tissue interface.

SRA Developments has developed Laparoscopic Operation by Torsional UltraSound (LOTUS®) which utilises torsional vibration mode. The blade tip (and equally spaced points along the waveguide) vibrates back and forth in a short arc around the waveguide axis.

In a transverse standing wave the waveguide acts like a vibrating violin string with antinodes vibrating in a plane. The distal end would be moving directly into tissue contacting its side, but this wave type suffers too heavy losses to transfer energy.

Methods (1)

1. A calorimeter is a thermally insulated instrument used to measure the energy exchange between a reaction system and its environment.
2. Calorimetry experiments were performed to measure the amount of electrical energy transformed into thermal energy by ultrasonic instruments.
3. The calorimeter contained polyethyleneglycol (PEG). This was chosen for its chemical stability, heat capacity and conduction properties. Specific Heat Capacity of PEG = 39.914 J/K/kg.
4. We assessed and compared instruments adopting longitudinal (Ethicon Harmonic Scalpel®) and torsional (Laparoscopic Operation by Torsional UltraSound®; LOTUS) vibration modes.
5. Differently shaped waveguide tips were also compared with the different vibration modes;
    a. Faceted waveguide; torsional
    b. Hook; torsional and longitudinal versions
    c. Shears using longitudinal vibration mode

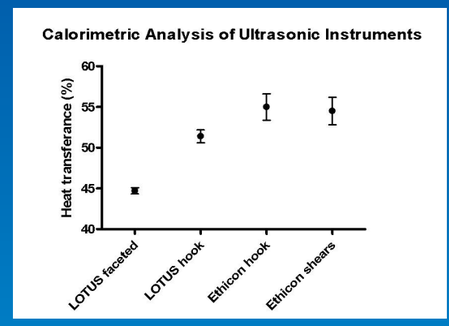
Methods (2)

1. Fresh porcine tissue (liver, kidney and loin) was cut into roughly equal samples.
2. Each sample was weighed before and after dissection to estimate the amount of tissue destroyed during the dissection process.
3. Tissue volume was measured before and after dissection using a measuring cylinder containing a known volume of water, and the volume displaced by the tissue used as an estimation of the tissue volume (ml). This estimated volume loss.
4. A surgical instrument was used to bisect the sample longitudinally, then to bisect each half transversely. UCCDs were used on their high power setting as recommended by the manufacturers.
5. The time taken for dissection was measured with a stopwatch to the nearest second.
6. Steps 2-5 were carried out with all 5 instruments on the 3 types of tissue.
7. For each tissue type and instrument, 6 runs were performed, all by the same investigator.

Results (1)

Blade	Vibration Mode	Generator Output (J)	Power transferred into Calorimeter (J)	Electrical Energy Transformed to Thermal Energy (%)
LOTUS "Faceted Waveguide"	Torsional	3228 [2940 – 3360]	1444 [1275 - 1536]	44.71 % [43.39 – 45.74]
LOTUS Hook	Torsional	2904 [2850 – 3000]	1493 [1428 - 1593]	51.39 % [49.7 – 53.5]
Ethicon Hook	Longitudinal	2730 [2670 - 2760]	1502 [1399 - 1686]	54.99 % [52.38 – 61.10]
Ethicon Shears	Longitudinal	2748 [2700 - 2760]	1498 [1353 - 1638]	54.49 % [50.14 – 58.34]

Figures are mean [range]. The Ethicon and LOTUS hooks are the only similar instruments, so comparative analysis was performed for these 2; $p>0.05$; there was no significant difference between them



Results (2)

Device	Speed of Dissection g/min (Mean +/-SD)		
	Liver	Kidney	Loin
LOTUS Hook	57.1±11.5	27.7±7.3	107.6±45.2
Ethicon Hook	51.7±17.6	42.1±10.0	90.6±27.4
p value	*0.5417*	*0.0192*	*0.4516*
LOTUS Shears	25.8±4.5	15.4±3.0	43.3±13.4
Ethicon Shears	12.5±2.0	19.0±3.9	22.1±3.7
p value	*<0.001*	*0.1096*	*0.0098*

Both types of Ultrasonic devices were more efficient at dissecting through tissues using the hook attachment compared to the shears ($p<0.001$)

Device	Mass Reduction g/min (Mean+/-SD)		
	Liver	Kidney	Loin
LOTUS Hook	3.10±0.89	1.49±0.19	1.05±0.41
Ethicon Hook	2.47±0.04	1.32±0.42	0.22±0.48
p value	*0.0649*	*0.3095*	*0.0152*
LOTUS Shears	1.18±0.18	1.17±0.28	0.09±0.58
Ethicon Shears	0.72±0.10	0.81±0.15	0.09±0.14
p value	*0.0022*	*0.0260*	*0.1320*

Device	Volume Reduction g/min (Mean+/-SD)		
	Liver	Kidney	Loin
LOTUS Hook	4.54±2.97	2.01±0.76	1.34±1.48
Ethicon Hook	3.00±1.02	1.94±1.28	0.00±0.00
p value	*0.5220*	*0.1135*	*<0.050*
LOTUS Shears	1.73±0.35	1.39±0.56	1.95±0.38
Ethicon Shears	0.78±0.34	1.13±0.21	0.57±0.69
p value	*0.4100*	*0.0902*	*0.0043*

Conclusions

Ultrasonic instruments cut through tissues by applying 4 types of force; compression, fluid cavitation, friction and shear. By performing calorimetry experiments, we have compared the friction force delivered by ultrasonic instruments using different vibration modes and waveguide tips. A smooth blade transferred virtually no thermal energy into the calorimeter, but when facets were cut into it, almost half the electrical energy used by the generator was transformed into thermal energy. There was no significant difference in energy delivery between those with similar shaped waveguide tips using torsional or longitudinal vibration.

An ex-vivo bench experiment was performed using porcine liver, kidney and loin to investigate speed of tissue dissection and rates of volume and mass lost during the process. In terms of dissecting speed, the LOTUS® shears were significantly faster than Ethicon® shears, with the Hooks being equivalent. There tended to be greater mass and volume reduction with LOTUS®. The devices have comparable efficiencies while dissecting through ex-vivo porcine tissues, but LOTUS® tends to be faster; resulting in greater mass and volume reduction rates. These ex-vivo findings are consistent with the perceived clinical perception that LOTUS® (torsional vibration) instruments dissect through tissues faster than the Ethicon Harmonic Scalpel® (longitudinal vibration).

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Conflicts of Interest

None declared

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