Temperature Assessment in the Drilling of *Ex Vivo* Bovine and Porcine Cortical Bone Tissue

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Introduction

The drilling bone process is a common surgical procedure on medicine. The main concern in these surgeries is the thermal damage of the bone tissue induced by inappropriate parameters [1].

Objectives:

- Analyze the optimum cutting conditions that generate the lower temperature.
- Drill speed and the feed-rate effects were studied during the drilling of animal bones.
- Experimental tests were performed in laboratory and clinical environment.

Experimental methods

- Fresh femurs (bovine and porcine) were obtained in a local butchers to the *ex-vivo* study.
- In clinical environment only bovine femurs were used. The femurs were kept untouched and the holes were made respecting a real surgery.
- An appropriate tool, dedicated to traumatology was used and allows a maximum drill speed of 900 rpm.
- The time of drilling and the depth of the holes were measured in order to obtain the feed-rate.

Tab. 1 Average of feed-rates used in the clinical procedure

Fresh bovine femurs	Feed-rate [mm/min]	
	Mean ± SD	[Range]
1 (n=6)	17.77 ± 3.04	[14.54-22.50]
2 (n=6)	29.73 ± 4.89	[23.44-36.00]
3 (n=5)	42.87 ± 8.40	[30.83-52.50]
4 (n=6)	45.22 ± 2.91	[42.27-49.09]
5 (n=6)	49.94 ± 2.45	[47.50-53.33]
6 (n=6)	55.23 ± 3.99	[52.50-63.00]
7 (n=6)	58.76 ± 6.27	[53.33-70.00]
8 (n=6)	64.24 ± 5.84	[55.00-70.00]

n number of the holes, *SD* Standard deviation

- In laboratory environment were used bovine and porcine femurs. The samples have been prepared to obtain just the cortical bone tissue.

- Different parameters were used to evaluate the influence on the drilling process.

Tab. 2 Parameters used in laboratory procedure

Parameters	*Ex vivo* bovine bones	*Ex vivo* porcine bones
Drill diameter	4 mm	4 mm
Drill point angle	118º	118º
Depth of the holes	8 mm	5 mm
Drill speed [rpm]	800, 900	600, 800, 1200
Feed rate [mm/min]	50	25, 50, 75

- In both methods only the thermal camera was used to measure the temperature in drill bit, before and after of drilling process.
- The results were organized in two groups: clinical and laboratory procedure.

Results

Tab. 3 Variation of temperature from drill bit, before and after drilling, in clinical procedure

Bovine	Feed-rate [mm/min]	ΔT [ºC]	
		Mean ± SD	[Range]
1 (n=6)	17.77	28.17 ± 6.21	[19.20-33.90]
2 (n=6)	29.73	22.37 ± 4.44	[15.90-26.70]
3 (n=5)	42.87	18.50 ± 5.48	[12.20-26.40]
4 (n=6)	45.22	16.32 ± 1.72	[14.00-18.10]
5 (n=5)	49.94	20.46 ± 5.95	[10.00-24.90]
6 (n=6)	55.23	14.90 ± 4.58	[11.00-23.30]
7 (n=6)	58.76	14.37 ± 4.96	[7.00-20.20]
8 (n=6)	64.24	15.12 ± 5.20	[8.70-21.40]

SD Standard Deviation, *ΔT* Temperature variation

Tab. 4 Variation of temperature from drill bit, before and after drilling, in *ex vivo* bovine samples

Ex vivo bovine samples				
Drill speed [rpm]	Feed-rate [mm/min]		ΔT [ºC]	
			Mean ± SD	[Range]
800	50	(n=23)	39.80 ± 6.57	[32.80-48.37]
900	50	(n=25)	39.78 ± 2.08	[35.55-47.02]

Tab. 5 Variation of temperature from drill bit, before and after drilling, in *ex vivo* porcine samples

Ex vivo porcine samples				
Drill speed [rpm]	Feed-rate [mm/min]		ΔT [ºC]	
			Mean ± SD	[Range]
600	50	(n=7)	28.22 ± 6.20	[20.40-34.20]
1200	50	(n=7)	36.60 ± 3.49	[31.00-41.20]
800	25	(n=7)	26.42 ± 6.51	[15.90-33.90]
	50	(n=5)	18.36 ± 1.82	[16.10-21.10]
	75	(n=7)	18.87 ± 1.46	[16.80-20.80]

- Temperature increases with an increasing drill speed and decreases with high feed-rates.
- The drilling temperatures on the bovine bone were higher than porcine samples.

Conclusions

- Clinical and laboratory procedures show that the feed-rate, the drill speed and the cortical thickness, are essential parameters in the prediction of temperature rise, and reduce the damage level in the bone.
- The application of high feed-rates reduce the heat generated during bone drilling process and decreasing the osteonecrosis in cortical bone tissue.

[1] Fernandes et al. *Revista da Associação Portuguesa de Análise Experimental de Tensões*, 24:71-77, 2015.

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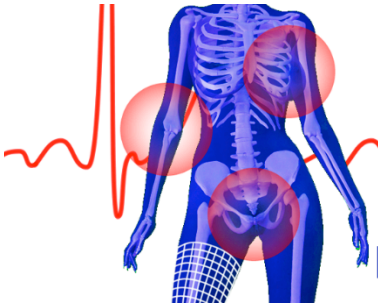

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