Combined Magnetic Fields Provide Robust Coverage for Interbody and Posterolateral Lumbar Spinal Fusion Sites

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Introduction

Combined magnetic fields (CMF) have proven efficacious in the clinic as an adjunctive therapy for lumbar spinal fusion [1]. A CMF bone growth stimulator generates an extremely low frequency and extremely low intensity electromagnetic field that has both AC and DC components. Specifically, the magnetic field for a CMF device at the calibration point is ±200 mG at a frequency of 76.6 Hz with a DC bias of 200 mG.

The purpose of this study was to model the therapeutic field associated with a bone growth stimulator utilizing CMF. The model was first exercised to test the hypothesis that CMF provide targeted and complete coverage of lumbar spinal fusion sites for both interbody and posterolateral procedures. An additional hypothesis was tested to determine whether the therapeutic effect of CMF stimulation for spinal fusions is a result of the induced electric field.

Methods

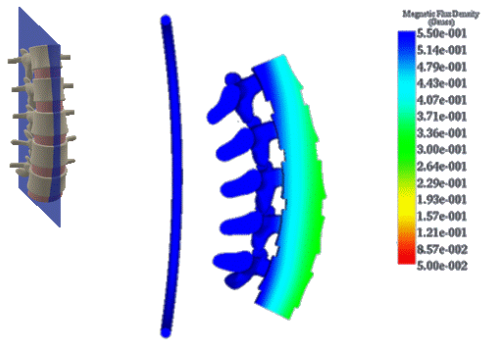
A realistic anatomical model of the vertebrae and discs of the lumbar spine was developed to represent interbody and posterolateral fusion sites. The interbody fusion model was created by replacing the tissue within the intervertebral spaces with cancellous bone as the graft material. The posterolateral fusion model was created by reducing the bone on the posterior faces to simulate decortication and replacing the tissue with cancellous bone.

Clinical data from Linnovitz et al. [1] was used to estimate the lower limit for the magnitude of the magnetic field, |**B**|, that was efficacious. Specifically, a lower limit for |**B**| of 220 mG was calculated for successful fusions occuring at the L4-L5 level. No therapeutic upper limit was assumed for the magnetic field. Computer simulations of the CMF were then analyzed to determine coverage of the fusion sites based on these limits. The electric field was calculated from analytical expressions for a circular coil with a circumference equal to the perimeter of the SpinaLogic coil and programmed in MathCad (PTC, Needham, MA) [2].

Results

The simulation of |**B**| for the mid-sagittal plane provided targeted and complete coverage of all lumbar spinal fusion sites with a depth of penetration of ~6.0 inches.

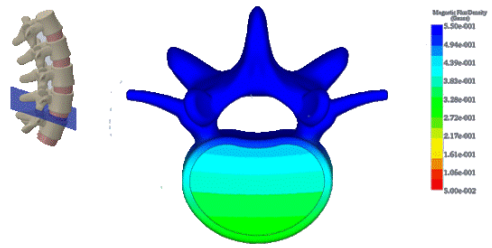
Magnetic Field for Mid-sagittal Plane



CMF provide robust coverage of all lumbar fusion sites.

For the interbody fusion model, CMF provided 100% coverage of the intervertebral fusion sites for all disc spaces from L1 to L5.

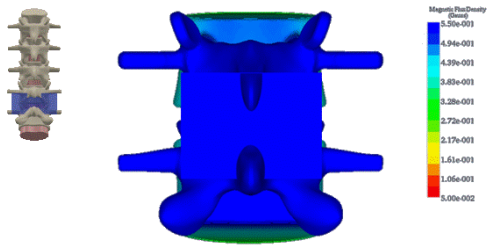
L4-L5 Interbody Fusion Coverage



CMF exceeds the therapeutic limit of 220 mG providing 100% coverage.

For the posterolateral fusion model, CMF also provided 100% coverage for all planes spanning the posterior aspect of the L1-L5 vertebrae.

L4-L5 Posterolateral Fusion Coverage



CMF exceeds the therapeutic limit of 220 mG providing 100% coverage.

Within the spinal column, the electric field, |**E**|, reached values on the order of 0.0001 V/m.

Conclusions

Simulations of the magnetic field confirmed complete and targeted coverage of the bone graft volumes for both interbody and posterolateral spinal fusion sites. In addition, the electric field was several orders of magnitude less than any reported study demonstrating a biological effect [3]. Given its clinical efficacy, a bone growth stimulator using CMF must rely on the action of its combined magnetic fields rather than its electric field for a therapeutic effect.

Learning Objectives

1) Discuss therapeutic coverage of interbody fusion sites by CMF.
2) Discuss therapeutic coverage of posterolateral fusion sites by CMF.
3) Identify role of electric field for a CMF device.

References

[1] Linovitz R, Pathria M, Bernhardt M, et al. Combined magnetic fields accelerate and increase spine fusion: a double-blind, randomized, placebo controlled study. Spine (Phila Pa 1976). 2002;27(13):1383-9.
[2] J. M. Griffith and G. W. Pan, "Time Harmonic Fields Produced by Circular Current Loops," IEEE Transactions on Magnetics, vol. 47, no. 8, pp. 2029-2033, 2011.
[3] ICINRP. Guidelines for limiting exposure to time-varying electric and magnetic fields (1 Hz to 100 kHz). Health Phys. Dec 2010;99(6):818-36

Acknowledgements

The authors would like to thank Ed Applegate, DJO Global, Vista, CA, for providing technical data on the CMF device.