Mathematical modelling for the analysis of the thermo-optical response of the cranial implant "Window to the Brain"

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Abstract

In the last few years the use of transparent nanocrystalline yttria-stabilized zirconia (nc-YSZ) ceramics has been explored as a biomedical transparent cranial implant, referred as the "Window to the Brain" (WttB). The purpose of WttB is to provide permanent optical access to the brain for diagnosis and therapeutic procedures. The aim of this work is to introduce the mathematical modelling of three scenarios for the analysis of the thermo-optical response of the WttB to irradiation from different laser sources [1].

Scenario I consists of a WttB sample subjected to laser irradiation. The objective of the mathematical modeling in this study is to reproduce previous experimental measurements, in order to verify the physical properties of the WttB material, in particular the thermal conductivity k, the convection coefficient h, the absorption coefficient α and the reflection coefficient R. The results provided by this scenario will be used in more complex schemes in subsequent studies.

Scenario II consists of a multilayered study. In addition to the WttB, a layer of bacteria and a layer of agar underneath the WttB are introduced. The objective of the mathematical model in this study is to determine whether the temperature increase due to the effect of laser irradiation is sufficient to eliminate the bacteria which can grow beneath the implant. Furthermore, this study supports and reproduces experimental measurements on the surface of the WttB.

Scenario III consists of laser irradiation on a disk with four layers: the WttB, a thin layer of copper nanoparticles, a layer of bacteria and a layer of agar. Nanoparticles contribute to the model providing a layer with an extremely high optical absorption coefficient, due to the effects of a property of the nanoparticles known as surface plasmon resonance. The objective of this model is therefore to achieve a localized increase in the temperature of the layer of bacteria, with no propagation to adjacent tissues, allowing bacteria elimination while avoiding tissue damage.

References

[1] Mildred S.Cano-Velázquez, Jose Bon, M.Llamazares, Santiago Camacho-López, Guillermo Aguilar, Juan Hernández-Cordero, MacarenaTrujillo, Experimental and computational model approach to assess the photothermal effects in transparent nanocrystalline yttria stabilized zirconia cranial implant. *Elsevier. Computer Methods and Programs in Biomedicine*, Volume 221, June 2022, 106896.