

# Mechanical design, analysis, and laboratory testing of a dental implant with axial flexibility similar to natural tooth with periodontal ligament

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Ömer Pektaş<sup>1,2</sup> and Ergin Tönük<sup>1,3,4</sup>

## Abstract

At the interface between the jawbone and the roots of natural teeth, a thin, elastic, shock-absorbing tissue, called the periodontal ligament, forms a cushion which provides certain flexibility under mechanical loading. The dental restorations supported by implants, however, involve comparatively rigid connections to the jawbone. This causes overloading of the implant while bearing functional loading together with neighboring natural teeth, which leads to high stresses within the implant system and in the jawbone. A dental implant, with resilient components in the upper structure (abutment) in order to mimic the mechanical behavior of the periodontal ligament in the axial direction, was designed, analyzed in silico, and produced for mechanical testing. The aims of the design were avoiding high levels of stress, loosening of the abutment connection screw, and soft tissue irritations. The finite element analysis of the designed implant revealed that the elastic abutment yielded a similar axial mobility with the natural tooth while keeping stress in the implant at safe levels. The in vitro mechanical testing of the prototype resulted in similar axial mobility predicted by the analysis and as that of a typical natural tooth. The abutment screw did not loosen under repeated loading and there was no static or fatigue failure.

## Keywords

Dental implant, elastic abutment, periodontal ligament

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## Introduction

Periodontal ligament (PDL) is a collagenous connective tissue, completely covering tooth roots. It separates teeth from the alveolar bone and forms an elastic cushion at the interface of the jawbone and tooth roots, thus enabling slight movement of the tooth under mechanical forces. The shocks that would have probably been induced by the forces created during biting or chewing are absorbed by uniform distribution of induced stresses so that teeth and alveolar bone structures are protected from being harmed.<sup>1</sup>

Tooth loss is reported to cause resorption in the jawbone, tilting of neighboring teeth toward the empty location, and possibly more tooth loss. This leads to reduced chewing capacity and esthetic and speech problems and therefore needs treatment.<sup>2</sup> Among other treatment alternatives, dental implants together with dental bridges and removable partial or complete dentures are widely used because of its favorable properties. One of the major mechanical differences between a natural tooth and a dental implant is the elastic

connection of natural teeth to jawbone by PDL versus relatively rigid connection of the implant.<sup>3</sup> This motivated many researchers to mimic mechanical behavior of PDL in implants in four different ways:

1. Producing the implant using a material with a lower elastic modulus than metals (e.g. polymers), which would both reduce the stresses at the bone–implant interface and damp the shocks transmitted

<sup>1</sup>Department of Mechanical Engineering, Middle East Technical University, Ankara, Turkey

<sup>2</sup>Genamer Technology Ltd., Ankara, Turkey

<sup>3</sup>Graduate Program of Biomedical Engineering, Middle East Technical University, Ankara, Turkey

<sup>4</sup>BIOMATEN – Center of Excellence in Biomaterials and Tissue Engineering, Middle East Technical University, Ankara, Turkey

## Corresponding author:

Ergin Tönük, Department of Mechanical Engineering, Middle East Technical University, Dumlupınar Boulevard No. 1, Universities District, TR-06800 Ankara, Turkey.  
Email: tonuk@metu.edu.tr