

# **In vivo and in vitro studies of polyetheretherketone: bone formation, inflammatory response and biofilm formation**

Akademisk avhandling

Som för avläggande av odontologie doktorsexamen vid Sahlgrenska akademien, Göteborgs universitet kommer att offentligens förvaras i F-sal 3, Medicinaregatan 12 A-G, den 26 april 2019, klockan 9.00.

av Sargon Barkarmo

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## **Avhandlingen baseras på följande delarbeten**

- I. Barkarmo S, Wennerberg A, Hoffman M, Kjellin P, Breeding K, Handa P, Stenport V. Nano-hydroxyapatite-coated PEEK implants: a pilot study in rabbit bone. *J Biomed Mater Res A*. 2013 Feb;101(2):465-71.
- II. Barkarmo S, Andersson M, Currie F, Kjellin P, Jimbo R, Johansson CB, Stenport V. Enhanced bone healing around nanohydroxyapatite-coated polyetheretherketone implants: An experimental study in rabbit bone. *J Biomater Appl*. 2014 Nov;29(5):737-47.
- III. Barkarmo S, Östberg AK, Johansson CB, Franco-Tabares S, Johansson PH, Dahlgren U, Stenport V. Inflammatory cytokine release from human peripheral blood mononuclear cells exposed to polyetheretherketone and titanium-6 aluminum-4 vanadium in vitro. *J Biomater Appl*. 2018 Aug;33(2):245-258.
- IV. Barkarmo S, Longhorn D, Leer K, Johansson CB, Stenport V, Franco-Tabares S, Kuehne S, Sammons R. Biofilm formation on PEEK and Titanium surfaces. *Manuscript Submitted*.

**SAHLGRENKA AKADEMIN  
INSTITUTIONEN FÖR ODONTOLOGI**



# **In vivo and in vitro studies of polyetheretherketone: bone formation, inflammatory response and biofilm formation**

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## **Abstract**

In prosthetic dentistry, restorative materials are used to replace missing teeth and tissues, so as to maintain oral functionalities and comfort for the patient. Depending on the clinical problem, metals, ceramics or polymers, are used both in dentistry and orthopedics. The present thesis focuses on the polymer material polyetheretherketone (PEEK), which has been used in orthopedic applications for about 30 years, mainly as a component of spinal devices - as such it has provided good clinical outcomes. PEEK has recently been adopted as part of dental rehabilitation owing to its many favorable properties, including high-level mechanical strength, chemical resistance, and biocompatibility. Therefore, it is of interest and important to extend our basic understanding of PEEK as a material that can be used in various prosthetic devices. Moreover, it is important to investigate whether modifications made to the surface of the material generate outcomes that may be translated to prosthetic dentistry, thereby using PEEK as a more broadly applicable dental material.

The overall aim of this thesis was to use in vivo and in vitro experimental methods to investigate the potential of PEEK as a material for use in dental devices.

In vivo studies were conducted to investigate the host bone responses to cylindrically shaped and threaded PEEK implants that were coated with nanocrystalline hydroxyapatite (nanoHA), as compared to uncoated control implants. The results revealed significantly higher mean values for the biomechanical and histomorphometric parameters for the nanoHA PEEK, as compared to the control material.

The levels of cytokines expressed by peripheral blood mononuclear cells (PBMCs) when exposed in vitro to PEEK, blasted PEEK, and titanium 6-aluminum 4-vanadium (Ti6Al4V) were investigated at different time-points. The PBMCs produced significantly higher levels of pro-inflammatory cytokines when exposed to the PEEK surface than when exposed to the Ti6Al4V surface. The blasted PEEK surface induced the highest level of pro-inflammatory cytokine release from the PBMCs.

The ability to form a biofilm in vitro was assessed by inoculating oral bacterial species onto PEEK, blasted PEEK, commercially pure titanium (cp-Ti), and Ti6Al4V. Biofilm formation was quantified after staining with crystal violet. The blasted PEEK showed increased biofilm formation by *S. sanguinis*, *S. oralis* and *S. gordonii* as compared to the other surfaces, while the levels of bacterial adhesion to PEEK, cp-Ti, and Ti6Al4V were similar.

It appears that nanoHa-coated, threaded PEEK implants improve bone formation, as compared to uncoated PEEK implants, and that PEEK induces a stronger inflammatory response than does Ti6Al4V. The biofilm formation results suggest that the level of bacterial adhesion to PEEK is similar to that of cp-Ti and Ti6Al4V.

Within the limitations of the methods used in the present thesis, it can be concluded that PEEK may have potential as a material for use in various dental applications.

**Keywords:** PEEK, polyetheretherketone, hydroxyapatite, nanotopography, osseointegration, cytokines, biofilms, biomaterials, dental materials, titanium, nanocoated.