A Cost-Effective Approach to Enhance PEEK Roughness and Osteoblast Adhesion Using Sodium Chloride as a Pore-Forming Agent

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INTRODUCTION

- Polyether ether ketone (PEEK) is a thermoplastic polymer that mimics the biomechanical properties of bone.[1]
- However, applications are limited by its bio-inert properties which inhibit osteoblast adhesion and differentiation.[2]
- Functionalization methods like laser etching, plasma treatments, and sandblasting are costly and require specialized equipment.[3]
- The goal of this study is to use sodium chloride (NaCl) as a cost-effective method to enhance the porosity, roughness, and cell adhesion to PEEK.
- Pore size and percentage can be controlled by adjusting the NaCl particle size and amount in the PEEK powder during implant fabrication.[4]
- We hypothesize that incorporating NaCl crystals into PEEK powder will generate pores on the surface of the prepared discs, mimicking osteoclast resorption pits and promoting bone formation.

METHODS

- NaCl powders were finely ground and hand-sieved using a 30 µm stainless steel sieve.
- PEEK granules were mixed with 0% to 50% (by mass) of 30 µm NaCl.
- A two-layer pellet, consisting of a 50% NaCl/PEEK mixture and pure PEEK, was placed into a metal mold, pressed, and sintered at 380°C for 10 minutes.
- Disc samples (Ø 10 mm × 2.5 mm) were formed, and the porogen was removed by leaching in deionized water for 48 hours.

Figure 1: PEEK discs fabrication method diagram.

- Wettability was assessed through contact angle measurement.
- Surface roughness was evaluated using a 3D optical profilometer.
- Osteoblast adhesion was analyzed using Trypan Blue quantification.
- Cell proliferation was measured via AlamarBlue assay.
- Differentiation was determined by alkaline phosphatase activity and calcium deposition.

RESULTS

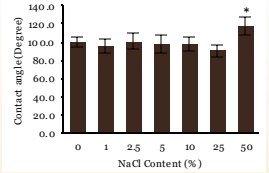

Figure 2: The wettability of PEEK discs remained unchanged with increasing NaCl concentrations, except at 50%, where large pores trapped air, increasing hydrophobicity (n=5).

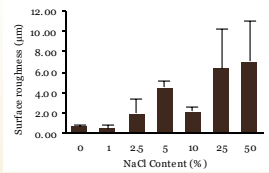

Figure 3: The surface roughness of PEEK discs increases with higher NaCl content, peaking at 25% and 50% NaCl, which results in higher surface porosity (n=2).

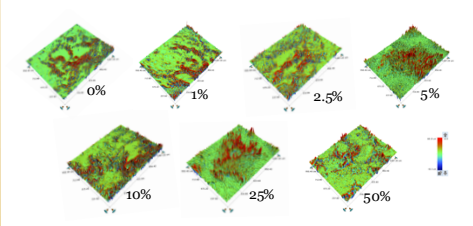

Figure 4: Photomicrographs of surface topography of PEEK discs with increased concentrations of NaCl. Red represents high peaks.

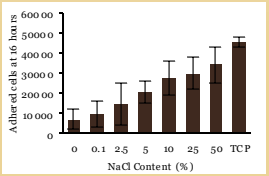

Figure 5: Cell adhesion at 16 hours increases with NaCl concentration, with 50% NaCl content exhibiting three times the number of adhered cells compared to the non-porous PEEK (n=2).

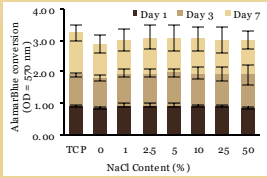

Figure 6: Osteoblast Proliferation shows similar AlamarBlue conversion levels across all samples, indicating no significant effect of PEEK porosity on osteoblast proliferation (n=3).

RESULTS

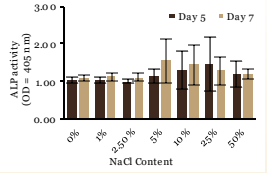

Figure 7: ALP activity of osteoblasts cultured on PEEK with varying NaCl content/porosities showing a slight increase at 5%, 10%, and 25% NaCl (n=2).

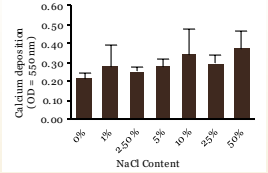

Figure 8: Calcium deposition by osteoblasts cultured for 7 days on PEEK discs shows a trend of increased mineral deposition as NaCl content/porosity increases (n=2).

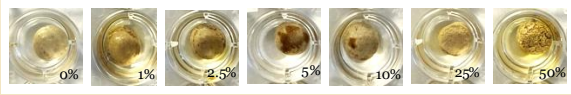

Figure 9: Calcium deposition by osteoblasts cultured for 7 days on PEEK discs using Alizarin red staining (ARS).

CONCLUSION

- We successfully created porous PEEK using the NaCl leaching method.
- Osteoblast adhesion was enhanced with increased porosity due to higher NaCl content during PEEK discs fabrication.
- Increased surface porosity led to greater roughness without affecting hydrophilicity.
- While surface porosity enhanced cell adhesion, it had no impact on the metabolic activity of human osteoblasts.
- Additionally, increased surface porosity enhanced ALP activity and calcium deposition, which may support bone formation on PEEK implants.
- Further work focused on enhancing PEEK porosity and roughness by exploring different NaCl crystal sizes, could help identify the optimal pore size for osteointegration of PEEK.

REFERENCES

1. Luo C. et al., (2023) Polymers (Basel). 2. Almasi D. et al., (2016) Int J Biomater. 3. Chen Y. et al., (2024) Sci Rep. 4. Akkouch A. et al., (2011) J Biomed Mater Res A.