In Vitro and *In Vivo* Characterization of Porous Poly(methyl methacrylate) Implants for Osseous Space Maintenance Following Craniofacial Trauma

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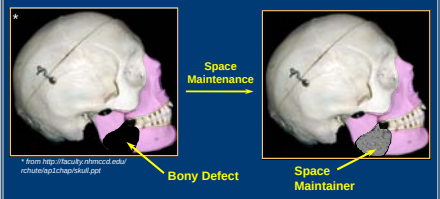
Space Maintenance Following Craniofacial Injury



* from http://faculty.nhmccd.edu/rchute/ap1chap/skull.ppt

- Maintain the necessary volume for later bone repair
- Provide physicians an accurate template over which to repair/regenerate soft tissue
- Prevent soft tissue in-growth without dehiscence and exposure of the materials

Motivation

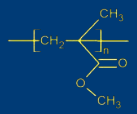
- Wound dehiscence and material exposure have been common problems associated with space maintenance.
- High porosity scaffolds are hypothesized to provide improved implant retention through tissue integration relative to solid or low porosity scaffolds.

Wound dehiscence in the region of the defect site of a rabbit mandible resulted from a solid poly(methyl methacrylate) (PMMA) space maintainer**

Intact soft tissue healing around defect sit resulted from a highly porous poly(propylene fumarate) (PPF) space maintainer**

** Nguyen et al., J. Oral Maxillofac. Surg., submitted

Materials



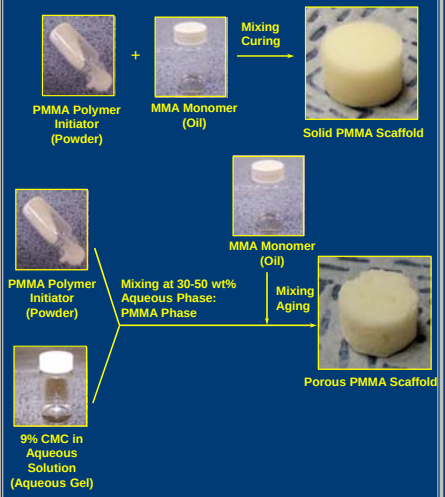
poly(methyl methacrylate) (PMMA)

- Regulated by U.S. Food and Drug Administration (FDA)
- Biocompatible and Nondegradable
- Able to be molded intraoperatively

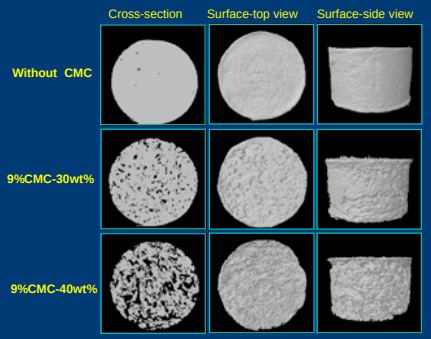
Experimental Objectives

To fabricate PMMA scaffolds with varying porosity and evaluate their space maintenance capabilities in a nonhealing rabbit mandibular defect model

Porous Scaffold Preparation by Mixing Carboxymethylcellulose (CMC)



Surface and Internal Characteristics by microCT



	Porosity	Interconnectivity
9%CMC-30wt%	16.9 ± 4.1%	39.7 ± 9.4%
9%CMC-40wt%	44.6 ± 2.1%	81.2 ± 1.0%

Increasing the weight percentage of CMC gel vs. PMMA resulted in greater construct porosity and pore interconnectivity.

In Vivo Study Model

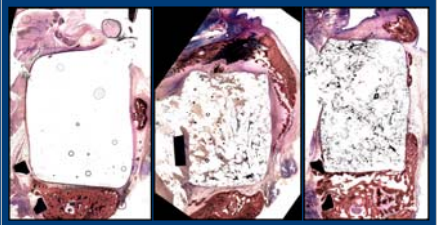
A nonhealing rabbit mandibular defect model with intraoral communication

- Implanted solid, low porosity, and high porosity PMMA scaffolds
- Characterize wound healing, integrity, and space maintenance over 12 weeks

Gross Wound Appearance

Healing without (left) and with (center and right) implant exposure (indicated with yellow arrows).

Histological Sections



Representative micrographs with solid (left) and porous (center and right) implants.

Histological Scoring

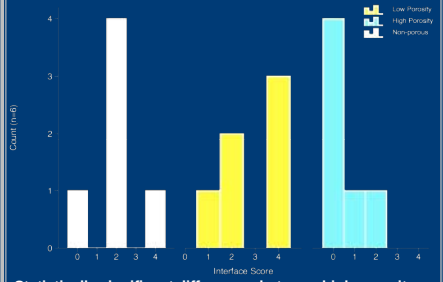
Quantitative Histological Scoring Guide

Description	Score
Tissue response at implant-bone interface	
Direct bone to implant contact without soft interlayer	4
Remodeling lacuna with osteoblasts and/or osteoclasts at surface	3
Majority of implant is surrounded by fibrous tissue capsule	2
Unorganized fibrous tissue (majority of tissue is not arranged as capsule)	1
Inflammation marked by an abundance of inflammatory cells and poorly organized tissue	0
Tissue response within implant pores	
Tissue in pores is mostly bone	4
Tissue in pores consists of some bone within mature, dense fibrous tissue and/or a few inflammatory response elements	3
Tissue in pores is mostly immature fibrous tissue (with or without bone) with blood vessels and young fibroblasts invading the space with few macrophages present	2
Tissue in pores consists mostly of inflammatory cells and connective tissue components in between (with or without bone) OR the majority of the pores are empty or filled with fluid	1
Tissue in pores is dense and exclusively of inflammatory type (no bone present)	0

In Vivo Healing Results

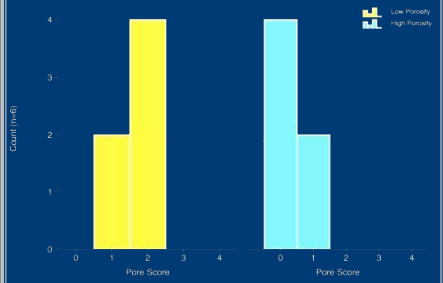
Implant type	Healed/Non-healed	Average minimum gingival tissue thickness (μm, mean ± SD)
Solid	3/3	559 ± 731
Low Porosity	5/1	1310 ± 1100
High Porosity	5/1	1439 ± 1113

Response at Bone-Implant Interface



Statistically significant differences between high porosity implants and both low porosity and non-porous implants were observed (pair-wise DSCF test).

Response within Pores of Implants



Statistically significant differences in pore scoring between high porosity implants and low porosity implants were observed (Mann-Whitney U test).

Conclusions

1. Porous PMMA implants can be fabricated using an aqueous phase containing CMC to impart porosity.
2. Porous implants promote or enable wound healing and maintained soft tissue coverage at 12 weeks post-implantation relative to non-porous implants.
3. Low porosity implants have a more favorable tissue interface and less inflammatory tissue filling the pores when compared to high porosity implants.