Compressive Strength and Morphological Evaluation of α-Tricalcium Phosphate Based on Light-Activated Pulp Capping Material

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Abstract

Pulp Capping is one of the teeth treatments indicated with deep caries with or without involving the pulp. Pulp capping treatment itself is carried out by applying a material that can stimulate odontoblasts to form reparative dentin. The material commonly used for pulp capping treatment until recent is calcium hydroxide [$Ca(OH)_2$]. However, $Ca(OH)_2$ has disadvantages, such as tunnel defects. One of the materials considered an innovation in pulp capping treatment is calcium phosphate incorporated into the resin matrix. Alpha Tricalcium Phosphate (α-TCP) is one of the materials that meet the general requirements of a pulp capping agent. α-TCP has the ability to stimulate reparative dentin formation. In this study, 50% α-TCP, 10% Zirconium oxide (ZrO_2), 3-Trimetoxysilil propyl methacrylate (Silane), 30% Urethane Dimethacrylate (UDMA), 10% Triethylene glycol dimethacrylate (TEGDMA), and Camphorquinone were employed as the composition, with matrix to filler ratio was 40:60. The control group is a commercial light-activated resin liner with $Ca(OH)_2$ filler. The compressive strength values were 98.53 ± 6.10 MPa for α-TCP Liner and 234.8 ± 19.32 for the control group. The morphological of the control group shows a more compact structure compared to the samples group. The composition of α-TCP Liner was still promising with the acceptance compressive strength and microstructure surface as a light-cured pulp capping material.

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Introduction

All treatments in the field of dentistry generally prioritize maintaining pulp vitality. Pulp Capping is one of the treatments indicated on teeth with deep caries or involving the pulp. Pulp capping treatment itself is carried out by applying a material that can stimulate odontoblasts to form reparative dentin. The material commonly used until now is calcium hydroxide [$Ca(OH)_2$].[1-3] $Ca(OH)_2$ works by forming a necrotic layer and then stimulates the formation of a reparative dentine layer under the necrotic layer. This mechanism of action is both an advantage and a disadvantage of $Ca(OH)_2$. The necrotic tissue formed by $Ca(OH)_2$ is considered too broad, and $Ca(OH)_2$ has high solubility so that at the time of the final restoration, it is feared that it will cause a void that can interfere with the long-term durability and strength of the restoration.[1-4] Another material considered as the standard for pulp capping treatment is mineral trioxide aggregate (MTA). MTA is considered more biocompatible, bioactive and does not cause extensive tissue necrosis to stimulate secondary dentin formation.[1-4]

One of the materials considered an innovation in pulp capping treatment is a calcium phosphate incorporated into the resin matrix and set under a light-cured process. It has several advantages: high mechanical strength, setting ability, and high release of Ca^{2+} and PO_4^{3-} ions. Since the most innovative restorations in dentistry today are composite resins, the

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formation of these materials is also intended to better bond with composite resin restorations and have the strength to resist mastication forces. [6-14] Bioceramics are recently entering the world of root canal treatment materials, particularly in endodontics, used in regenerative endodontics therapy, surgeries, and as a sealer.[15-17] Alpha Tricalcium Phosphate (α-TCP) is a material with the general requirements to be a pulp capping agent. α-TCP has the ability to stimulate reparative dentin formation.[6,8,9,19,20] It is well known that calcium phosphate has an essential role in a ceramic's bioactive and bioresorbable properties.[6,8,9] α-TCP with the chemical formula of $Ca_3(PO_4)_2$ has calcium and phosphate components found in teeth and bone. Several previous studies showed that α-TCP gave comparable results to MTA in stimulating reparative dentin formation, and it has a lower solubility level than $Ca(OH)_2$.[19 - 21] Based on the above mentioned, we are interested in synthesizing light-cured pulp capping agents using α-TCP as a calcium phosphate-based liner incorporated in the resin matrix.

Materials and methods

α-TCP Liner Samples Preparation

The α-TCP (Taihei Co., Osaka, Japan), Zirconium oxide (ZrO_2) (Zirai Guangzhou Hongwu Material Technology Co., Guangzhou, China), 3-Trimetoxysilil propyl methacrylate (Silane) (Sigma Aldrich, Darmstadt, Germany), Urethane Dimethacrylate (UDMA) ((Sigma Aldrich, Darmstadt, Germany), Triethylene glycol dimethacrylate (TEGDMA) (Sigma Aldrich, Darmstadt, Germany), and Camphorquinone (Sigma Aldrich, Darmstadt, Germany) were used in this study with matrix to filler ratio was 40:60. The composition used in this study was 50% α-TCP;10% ZrO_2; 30% UDMA; and 10% TEGDMA. The filler was coated in silane and mixed with resin matrix (UDMA and TEGDMA), then camphorquinone was added as a photo initiator. The Control group is a commercial light-activated resin liner with $Ca(OH)_2$ filler under brand TG Caviliner (TGDent, London, UK).

Mechanical Strength Measurement

Mechanical strength was examined in terms of compressive strength. α-TCP Liner was injected layer by layer into mold (4 mm in diameter and 6 mm in height) and light-cured per 2 mm thickness. After the α-TCP Liner was set, each sample's diameter and height were measured with a micrometer. The sample was crushed using a universal testing machine (LRX Plus; Llyod Instruments, Ltd., West Sussex, UK) at 1 mm/min crosshead speed. Compressive strength values were taken from an average of at least fifteen samples.

Morphological observation

Morphological evaluation on the sample and control group's surface was evaluated by scanning electron microscope (SEM) (S-3400N, Hitachi High-Technologies, Tokyo, Japan) at 10 kV accelerating voltage after gold sputters coating.

Results

Figure 1 shows the Compressive Strength value of set α-TCP Liner. The compressive strength values were 98.53 ± 6.10 MPa for α-TCP Liner and 234.8 ± 19.32 for the control group. Compressive Strength measurement shows statistically significant between α-TCP Liner and the control sample ($p < 0.01$).

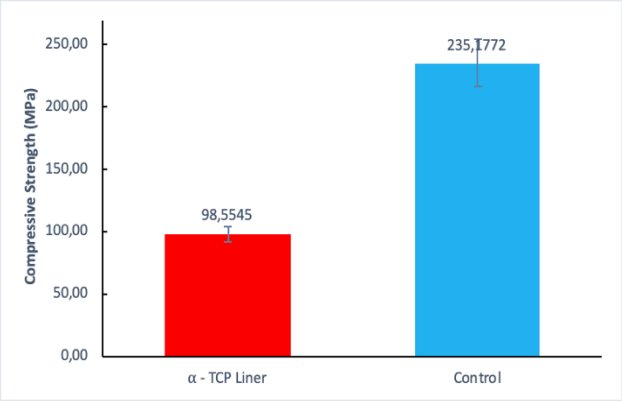

Figure 1. The compressive strength value of set α-TCP Liner and the control group.

Figures 2 shows SEM images of the set's microstructure surface α-TCP Liner and control group. The morphological SEM images of figures 2A and 2C show a more compact structure than figures 2B and 2D.

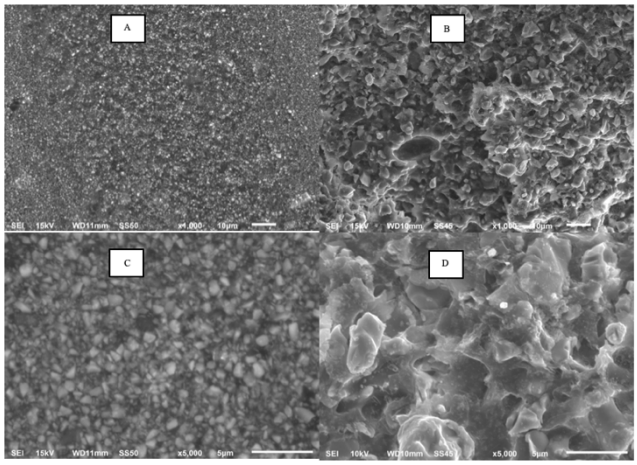

Figure 2. SEM images of the control group (A, C) and set α-TCP Liner (B, D). A and B 1000x magnification, C and D 5000x magnification.

Discussion

According to ISO 4046: Polymer-based restorative material, this α-TCP Liner aims to be type II (base and temporary restorative materials) which the minimum requirement for compressive strength is 5 MPa. This α-TCP Liner's compressive strength already more than the minimum requirement by ISO, even the control group had a higher compressive strength value. Until present, there are no commercialized products using α-TCP as a filler, so researchers cannot find a comparable product for determining average compressive strength with α-TCP as a filler. Meanwhile, when consideration is taken for mastication forces, this α-TCP Liner withheld force higher than the maximum biting force on the molar area (400 - 890 N).[22]

Morphological observation through SEM was clearly visible α-TCP fillers even though incorporated in a resin matrix. The control group appeared more compact and dense that might arise due to the difference in the matrix to filler ratio and related to the filler's particle size. This condition was supported by the mechanical strength results from the study, the control group had higher compressive strength than the samples. However, even the mechanical strength is lower, but it was still accepted as a pulp capping material. Furthermore, the α-TCP Liner can improve the quality of pulp capping material and the treatment itself because of the bioactive and biocompatibility properties of the α-TCP. The α-TCP Liner sample composition (50% α-TCP;10% ZrO_2; 30% UDMA;10% TEGDMA) has given adequate results. This primary research has given a promising material to continue this work with characterizing material.

Conclusions

Composition of α-TCP Liner used in this study giving a promising result of compressive strength and microstructure surface as a light-cured pulp capping material. Further research is needed for establishing this composition as a novel light–cured pulp capping material.

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Declaration of Interest

The authors report no conflict of interest.

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