行政院國家科學委員會專題研究計畫 成果報告

不同成份物質添加於根尖充填材料（矽鈣類合成物)後之生物活性研究

研究成果報告(精簡版)

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公 開 資 訊 ：本計畫涉及專利或其他智慧財產權，1 年後可公開查詢

中 華 民 國 101 年 08 月 16 日

中 文 摘 要 ： 明膠為膠原蛋白水解後之產物，與膠原蛋白有著相等之成份。過去研究 gelatin-chondroitin-hyaluronan 配製之化合物對於軟骨(chondrocyte)之再生與牙本質牙髓複合體（dentin-pulp complex)之再生，都有成功的表現。
本研究目的：於體外試驗，探討鈣矽類材料混合明膠後對骨細胞之生物上效應反應。
研究方法與材料
本研究細胞採用人類骨癌細胞株(MG63)作為研究。明膠與鈣矽化合物經前瞻試驗下，決定配製之濃度，以粒腺體呈色反應觀察細胞與材料之生長；以 RT-PCR 分析混合物作用下之細胞發炎訊號 IL1, COX-2, TNF-α, iNOS 和骨生成蛋白質訊號 Col, OC, ALP, BSP, 和 OPN 之表現。結果以統計軟體分析。
結果發現； 於第三、七與十五天之比較下，CS 和 gelatin 混合之生長狀況較單獨 CS 之生長狀況好($p<0.05$)。於第三天之觀察下發現發炎訊號之表現二組 之間表現差異性不大。而第三天下，骨訊息細蛋白之表現則以實驗組表現較為明顯。($p<0.05$) 結語；將鈣矽累化合物混合明膠，對於骨細胞之生長具有誘導作用且不會對於細胞造成發炎反應。

中文關鍵詞： 明膠、鈣矽化合物、發炎訊息蛋白、骨生成蛋白

英 文 摘 要 ： The purpose of present study was to evaluate the calcium silicate added gelatin compound osteoconduction and inflammatory effects in bone cell line. Gelatin and CS were mixed and poured in 2mm diameter, 3 mm height Teflon cylindrical tube. Human osteosarcoma cell line (MG63) was cultured with the CS and gelatin compound. The cell viability assay was done by mitochondria tetrazolium bromide colorimetric test. The reverse transcription-polymerase chain reaction (RT-PCR) were to detect the inflammatory markers IL1, COX-2, TNF-α and iNOS expression and the osteoconduction markers Col, OC, ALP, BSP, and OPN expression. Results were compared by using analysis of variance (ANOVA). Differences in treatment means were analyzed by using the Student-Newman-Keul test and were considered to be significant at $P < .05$. The results showed The cell viability assay showed that cell viability of CS combined gelatin group was statistically higher than

control and gelatin groups at third, seventh and fifteenth days culture ($p<0.05$). The inflammation reaction to experimental groups showed that IL1, COX-2, TNF-α and iNOS markers were with various degree of expression after third day culture. The BSP, OPN and OC bone marker expression by RTPCR assay showed higher in experiment groups after third days culture ($p<0.05$). Conclusion: The gelatin combined CS compound can increase the inflammatory marker expression at initial stage. The osteoconduction ability of gelatin combined CS compound was proved.

英文關鍵詞： Gelatin, calcium silicate cement； inflammation marker, bone markers

行政院國家科學委員會補助專題研究計畫
成果報告

（計畫名稱）

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計畫主持人：黃翠賢
共同主持人：高嘉澤
計畫參與人員：謝明佑、許瑛祺

成果報告類型(依經費核定清單規定繳交)：□精簡報告 ■完整報告

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中 華 民 國 101 年 08 月 16 日

目錄

中文摘要

明膠為膠原蛋白水解後之產物，與膠原蛋白有著相等之成份。過去研究 gelatin-chondroitin-hyaluronan 配製之化合物對於軟骨(chondrocyte)之再生與牙本質牙髓複合體（dentin-pulp complex)之再生，都有成功的表現。

本研究目的：於體外試驗，探討鈣矽類材料混合明膠後對骨細胞之生物上效應反應。

研究方法與材料

本研究細胞採用人類骨癌細胞株(MG63)作為研究。明膠與鈣矽化合物經前瞻試驗下，決定配製之濃度，以粒腺體呈色反應觀察細胞與材料之生長；以RT-PCR分析混合物作用下之細胞發炎訊號 IL1, COX-2, TNF-α, iNOS 和骨生成蛋白質訊號 Col, OC, ALP, BSP, 和 OPN之表現。結果以統計軟體分析。

結果發現； 於第三、七與十五天之比較下，CS和gelatin混合之生長狀況較單獨CS之生長狀況好($p<0.05$)。於第三天之觀察下發現發炎訊號之表現二組 之間表現差異性不大。而第三天下，骨訊息細蛋白之表現則以實驗組表現較為明顯。($p<0.05$) 結語；將鈣矽累化合物混合明膠，對於骨細胞之生長具有誘導作用且不會對於細胞造成發炎反應。

英文摘要

Abstract

The purpose of present study was to evaluate the calcium silicate added gelatin compound osteoconduction and inflammatory effects in bone cell line. Gelatin and CS were mixed and poured in 2mm diameter, 3 mm height Teflon cylindrical tube. Human osteosarcoma cell line (MG63) was cultured with the CS and gelatin compound. The cell viability assay was done by mitochondria tetrazolium bromide colorimetric test. The reverse transcription–polymerase chain reaction (RT-PCR) were to detect the inflammatory markers IL1, COX-2, TNF-α and iNOS expression and the osteoconduction markers Col, OC, ALP, BSP, and OPN expression. Results were compared by using analysis of variance (ANOVA). Differences in treatment means were analyzed by using the Student-Newman-Keul test and were considered to be significant at $P < .05$. The results showed The cell viability assay showed that cell viability of CS combined gelatin group was statistically higher than control and gelatin groups at third, seventh and fifteenth days culture ($p<0.05$). The inflammation reaction to experimental groups showed that IL1, COX-2, TNF-α and iNOS markers were with various degree of expression after third day culture. The BSP, OPN and OC bone marker expression by RTPCR assay showed higher in experiment groups after third days culture ($p<0.05$). Conclusion: The gelatin combined CS compound can increase the inflammatory marker expression at initial stage. The osteoconduction ability of gelatin combined CS compound was proved.

前言

1. Introduction

Mineral trioxide aggregate (MTA, Mailfer, Dentsply, Switzerland) is a calcium silicate based endodontic material that was developed at Loma Linda University in the 1990s. In 2009, an MTA-like material, calcium silicate (CS) cement, was developed in our laboratory [1]. Calcium silicate cement bonds to living bones by forming a bone-like apatite layer on their surfaces [2,3]. MTA can stimulate calcium deposition in the connective tissue of Wistar albino rats, and it is an important osteogenic inductor agent in *in vivo* studies [4]. In our previous studies, SiO_2, CaO, and Al_2O_3 were used to construct CS by high-temperature solid-state sintering [1,5]. CS showed similar biological effects as MTA. In an *in vitro* study, MTA and CS cement showed osteoconductive effects in an osteosarcoma cell line (MG63) [5].

The bioactivity of MTA can produce hydroxyapatite (HA) in the presence of phosphate-buffered saline (PBS) [6]. The calcium ions released by MTA react with phosphate in PBS and make an interfacial layer of HA in the MTA-dentin interface [6]. In a surgically derived human alveolar bone cell model, both ProRoot MTA and tooth-colored MTA supported cell attachment, proliferation, and matrix formation [7].

Gelatin is the denaturation product of collagen and a biocompatible, biodegradable polymer. Gelatin has numerous applications in the biomedical field, such as tissue engineering, wound dressing, drug delivery and gene therapy [8]. The study of the interactions of gelatin with calcium phosphates during crystallization provides useful information about the growth mechanism of biominerals [9]. The CS mixed with gelatin effects are interesting to be studied.

In the endodontic retrofilling technique, cement contacted the root apex on one side and the alveolar bone on the other side. The effects of the cement contacting bone tissue should be studied. CS has an osteoconductive ability [5], and gelatin is commonly used in tissue engineering. The bone mineralization effects of adding gelatin to CS material have not been reported yet. The purpose of the present study was to evaluate the osteoconductive and inflammatory effects of adding the CS to gelatin compound on an osteosarcoma cell line.

材料與方法

2. Materials and Methods

2.1 Specimen preparation

The CS cement was prepared as follows. Reagent-grade SiO_2 (High Pure Chemicals, Saitama, Japan), CaO (Riedel-deHaen, Steinheim, Germany), and Al_2O_3 (Sigma-Aldrich, St. Louis, MO) powders were used as matrix materials; while MgO (Sigma-Aldrich), ZnO (Wako, Osaka, Japan), and Fe_2O_3 (Showa, Tokyo, Japan) powders were used as additives. After heating, the sintered granules were then ball-milled for 6 hours in ethyl alcohol using a Retsch S 100 centrifugal ball mill (Hann, Germany). The 20 wt. % Bi_2O_3 (Sigma-Aldrich, St. Louis, MO) and 5 wt. % $CaSO_4 \cdot 2H_2O$ (Sigma-Aldrich, St. Louis, MO) powders were added to the sintered and ground powders to construct the solid phase of the calcium silicate material.

Gelatin cements were prepared using type A gelatin from pig skin. Gelatin at 30% of the total cement weight (1 g of gelatin in 10 ml of distilled water at 40°C) was added to the CS. After mixing, the suspension was poured into cylindrical Teflon tubes measuring 2 mm in diameter and 3 mm in height. The cements were stored in an incubator at 100% relative humidity and 37°C for 1 day of hydration. The cements were sterilized using ultraviolet (UV) light for 1 hour before application.

2.2 The cell viability assay

Cell viability was determined using the mitochondria tetrazolium bromide colorimetric assay (MTT). This assay was used to detect the ability of the cells to cleave the tetrazolium salt (3-[4,5-dimethylthiazol-2-yl]-2,5-diphenyl tetrazolium bromide) to a formazan dye. Additionally, 1×10^4 human osteosarcoma cells (MG63) were cultured with McCoy's medium at 5% CO_2 in a 37°C incubator. The cells were cultured directly on gelatin or gelatin combined with the CS compound [7].

The MG63 cells were harvested for an MTT assay at 1, 3, 7, and 15 days. Optical densities were measured at 570-600 nm in a multiwell spectrophotometer (Hitachi, Tokyo, Japan). Results were

compared using analysis of variance (ANOVA). Differences in treatment means were analyzed using the Student-Newman-Keuls test and were considered to be significant at $P < .05$.

2.3 Inflammation marker expression assay

The expression of the inflammation markers IL1, COX-2, TNF-α and iNOS were assayed by reverse-transcription polymerase chain reaction (RT-PCR).

MG63 cells were directly cultured with experimental treatments (gelatin or CS combined with gelatin) or the control treatment for 1, 3, 7 and 15 days and were then lysed with 1 mL Trizol reagent. Total RNA was isolated from the cells using the Charge Switch Total RNA Cell kit (Invitrogen, Taipei, Taiwan). After denaturation of total RNA at 70°C for 10 minutes, complementary DNA was synthesized using an oligonucleotide primer and reverse transcriptase (Invitrogen).

Polymerase chain reaction (PCR) amplification was performed using IL1 (sense primer, 5'-AATCCAGCAAGATGCAAGCC-3', antisense primer, 5'-ACGCCTTCGTCAGGCATATT-3'), TNF alpha (sense primer, 5′-ATGAAAGTCTCTGCCGCCCTCA-3′; antisense primer, 5′-GAG ATCTGTGCTGACCCCAA-3′), COX-2 (sense primer, 5'-TTCAAATGAGATTGTGGGAAAAT-3', antisense primer, 5'-AGATCATCTCTGCCTGAGTATCTT-3') and iNOS (sense primer, 5'-TGGATGCAACCCCATTGTC-3', antisense primer 5'-CCCGCTGCCCCAGTTT-3') primers. PCR products were separated by agarose gel electrophoresis and stained with ethidium bromide. The intensity of each band after normalization with actin mRNA was quantified using Scion Image software.

2.4 Bone markers expression assay

MG63 cells were directly cultured with experimental treatments (gelatin or CS combined with gelatin) or the control treatment for 1, 3, 7 and 15 days. Cells were lysed with 1 mL Trizol reagent. Total RNA was isolated from the cells using the Charge Switch Total RNA Cell kit (Invitrogen, Taipei, Taiwan). After denaturation of the total RNA at 70°C for 10 minutes, complementary DNA was synthesized using an oligo primer and reverse transcriptase (Invitrogen). Polymerase chain reaction (PCR) amplification was performed using the specific primers for type I collagen (Col, sense primer 5'-GATGGATTCCAGTTCGAGTATG-3', antisense primer 5'-GTTTGGGTTGCTTGTCTG TTTG-3'), osteocalcin (OC, sense primer 5'-ATGAGAGCCCTCACACTCCTC-3', antisense primer 5'-CGTAGAAGCGCCGATAGGC-3'),

alkaline phosphatase (ALP sense primer 5'-AGTTACTGGCGACAGCAAGC-3', antisense primer 5'-GAGTGGTGTTGCATCGCG- 3'), bone sialoprotein (BSP sense primer 5'-TCAGCATTTTGGGAA TGGCC-3', antisense primer 5'-GAGGTTGTTGTCTTCGAGGT-3'), and osteopontin (OPN sense primer 5'-ACGACCATGATTGGCAGTG-3', antisense primer 5'-TTACCTCAGTCCATAAGCAA-3'). PCR products were separated by agarose gel electrophoresis and stained with ethidium bromide.

To determine the expression levels of Col, OC, ALP, BSP, and OPN, the complementary DNA samples were analyzed by real-time PCR using an ABI PRISM 7300 unit (Applied Biosystems, Carlsbad, CA). The expression levels of each sample were normalized against β-actin messenger RNA expression.

3. Results

The cell viability assay showed that the viability of cells cultured with CS combined with gelatin was statistically higher than cells cultured with control or gelatin at 3, 7 and 15 days in culture ($p<0.05$) (Fig 1.).

The expression levels of the inflammatory markers IL1, COX-2, TNF-α and iNOS in the experimental groups were varied after 3 days in culture. (Fig. 2) At 15 days, the expression levels of IL-1, COX-2, TNF-α and INOS decreased in the cells cultured with gelatin or CS combined with gelatin ($p<0.05$).

The expression levels of BSP, OPN and OC assayed by RT-PCR were higher in the experimental groups after three days in culture ($p<0.05$) (Figure 3 a, b and e). The expression of ALP was higher in the experimental groups than the control group at 3 and 7 days, but the expression of ALP was lower than the control group at 15 days (Figure 3 c). The expression of type I collagen was not statistically different between the experimental and control groups ($p>0.05$) (Fig.3d).

4. Discussion

The cell viability assay showed that with increasing culture time, the proliferation of MG63 cells cultured in CS combined with gelatin is higher than that of cells cultured in control (Fig. 1). This assay showed that calcium silicate combined with gelatin is a bioactive material on MG63 cells.

This biocompatibility result is similar to calcium phosphate combined with gelatin on MG63 cells [10].

Calcium phosphates are biomaterials because of their good biocompatibility and bioactivity, which make these compounds particularly suitable for hard tissue replacement. In a previous study, osteoblast-like cells (MG63) were cultured on gelatin combined with calcium phosphate cement or calcium phosphate alone. The results of this study indicated that the presence of gelatin, which improves the setting properties of the calcium phosphate, favors osteoblasts' proliferation and differentiation and suggests that the biomimetic composite material could be applied as a bone substitute [10]. CS was shown to induce bone cell proliferation and be biocompatible [5]. Based on these data, the combination of gelatin with calcium silicate cement was evaluated to uncover its osteoconductive ability in the present study.

To detect inflammation effects of the CS combined with gelatin on MG63 cell, inflammatory markers were assayed. At 15 days in culture, the expression levels of the inflammatory markers IL-1, COX-2, TNF-α and iNOS decreased in cells cultured with gelatin or CS combined with gelatin as shown in figure 2. Proinflammatory cytokines, interleukin 1 (IL-1) and tumor necrosis factor-alpha (TNF-alpha) play an important role in initiating and perpetuating inflammation. Inducible COX-2 enzyme is the principal PGE_2-synthesizing COX under inflammatory conditions [11]. The production and activity of this enzyme are induced by proinflammatory cytokines, such as IL-1 or IFN-γ, NO, iNOS, bacterial LPS signaling, and ROS [12]. iNOS is expressed in numerous cell types, including endothelial cells and inflammatory cells in the presence of inflammatory stimuli such as cytokine signaling (e.g., TNF-α and IL-1β), bacterial LPS, and ROS [13]. In a previous study, mice deficient in inducible NOS (iNOS) exhibited altered bone healing. Increased bone mineral density has been reported in mice deficient in all three isoforms of NOS [14,15]. In our study, iNOS was decreased at 15 days. These data suggest that the bone might be in the healing process.

TNF-α, IL-1, and IL-6 are critical for the inflammatory response that triggers osteogenesis. IL-1 and TNF-α exhibit a biphasic response, with high levels expressed immediately following injury and levels becoming undetectable within 72 hours. At approximately 3 to 4 weeks post-injury, both IL-1 and TNF-α exhibit peaks, which may correspond to early phases of the remodeling process [16]. In our study, the inflammation markers were expressed most highly at 3 days in culture, and then expression decreased at fifteen days. These data suggest that the inflammatory

MG63 cells are recovering. This process is beneficial to the bone regeneration induced by the cement.

Calcium silicate cement enhances osteoblast differentiation and mineralization by stimulating proliferation, cell attachment, and spreading [17]. The present study showed that expression levels of BSP, ALP, OPN, and OC are higher in the experimental groups than in the control group. Bone alkaline phosphatase (ALP) is secreted by osteoblasts and is an important biochemical marker of bone formation. ALP is a significant component of the bone extracellular matrix and has been suggested to constitute approximately 8% of all noncollagenous proteins found in bone and cementum [18]. The highest ALP expression in MG63 cells was found at seven days in culture. Bone sialoprotein (BSP) is a component of mineralized tissues such as bone, dentin, cementum, and calcified cartilage. After seven days in culture, the expression level of BSP in MG63 cells was significantly higher in the experimental groups than in the control group. Osteocalcin is a noncollagenous protein found in bone and dentin. It is secreted by osteoblasts and thought to play a role in mineralization and calcium ion homeostasis [19]. The cells treated with CS and gelatin showed the highest level of OC expression at fifteen days in culture. Osteopontin is an extracellular structural protein and an organic component of bone. The expression level of OPN significantly increased until day seven and then decreased at day fifteen.

Adhesive interactions with extracellular matrix components, including fibronectin and type I collagen, play critical roles in osteoblast survival, proliferation, differentiation, and matrix mineralization as well as in bone formation [20]. The present data showed that expression of collagen I did not change from one day to fifteen days in culture between the control and the experimental groups. The viability assay showed that calcium silicate cement combined with gelatin has osteoblastic ability. The expression of inflammatory markers was higher in the beginning of the culture period and decreased with time. This study confirms that the osteoconductive effects were increased in cultures treated with calcium silicate cement mimetic and gelatin. These data agree that calcium silicate combined with gelatin compound can be an osteoconduction material.

結果與建議

本研究結果證明明膠加入鈣矽類材料後，對於骨細胞之生長有幫助，因此，也提供另類思考方向，即除材料原本之架構外，加入其它輔助之材料，可以增加效果表現。

由於本計畫為只通過一年期，因此只能就試管外之研究作揖探討，期望勢能進階到動物試驗。甚至人體實際試驗，以作為呼應。並可以開發初另類之骨生成材廖。

Legend

Figure 1. The viability of MG63 cells cultured with gelatin or calcium silicate combined with gelatin compound as measured by mitochondrial colorimetric assay.

Figure 2. The inflammatory reactions of the MG63 cells. The control group was cultured under blank conditions (control) and experimental groups were cultured with gelatin (Gel) or gelatin combined with calcium silicate (CS). The expression of the inflammatory markers IL1, COX-2, TNF-α and iNOS were assayed using reverse-transcription polymerase chain reaction (RT-PCR). a. The expression of COX-2 in MG63 cells. b. The expression of IL-1 in MG63 cells. c. The expression of iNOS in MG63 cells. d. The expression of TNF-α in MG63 cells. * = $p<0.05$

Figure 3. The osteoconduction reactions of the MG63 cells. The control group was cultured under blank conditions (control) and experimental groups were cultured with gelatin (Gel) or gelatin combined with calcium silicate (CS). The expression of the bone markers bone sialoprotein (BSP), osteopontin (OPN), alkaline phosphatase (ALP), type I collagen (Col I) and osteocalcin (OC) were assayed using reverse-transcription polymerase chain reaction (RT-PCR).

a. The expression of BSP in MG63 cells. b. The expression of OPN in MG63 cells. c. The expression of ALP in MG63 cells. d. The expression of Col I in MG63 cells. e. The expression of OC in MG63 cells. * = $p<0.05$

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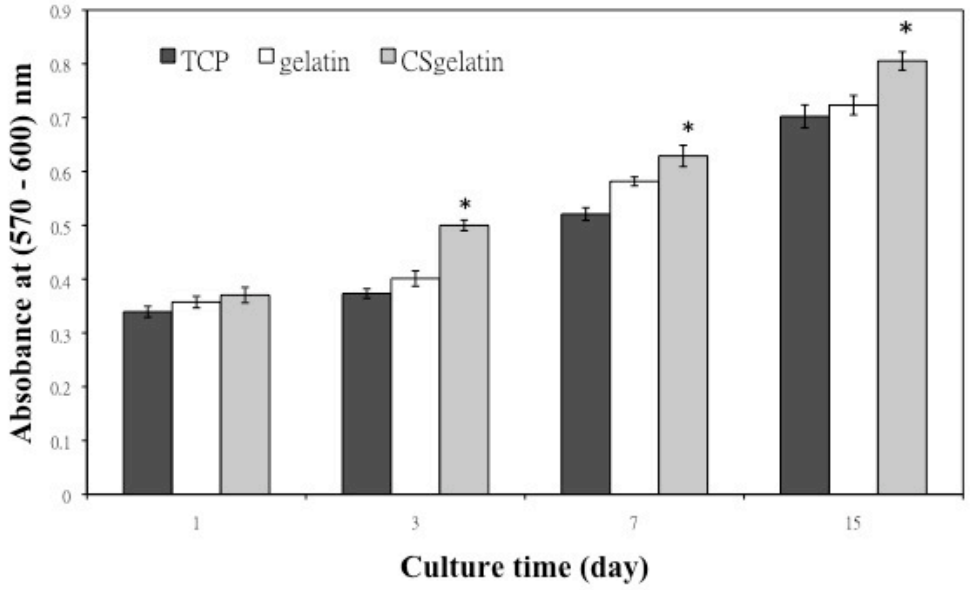
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gelatin
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Absobance at (570 - 600) nm
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*

Figure 1.

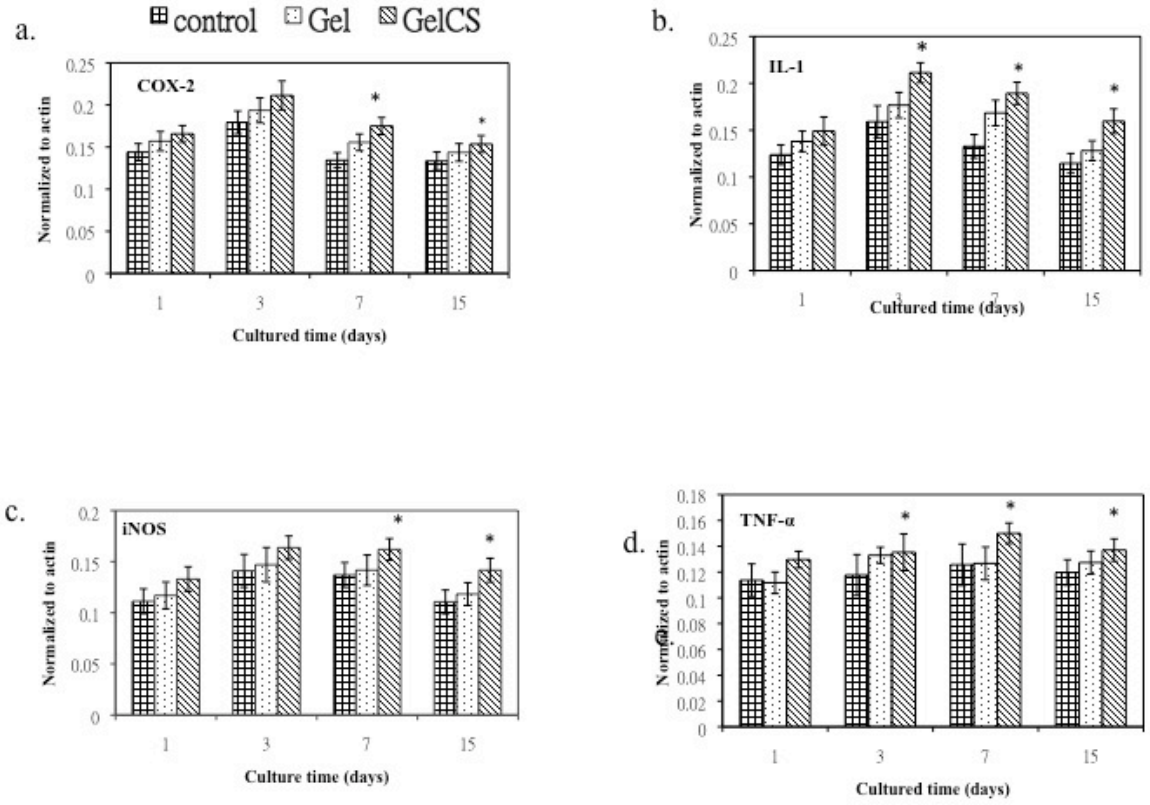
a.
control
Gel
GelCS
COX-2
Normalized to actin
Cultured time (days)
b.
IL-1
Normalized to actin
Cultured time (days)
c.
iNOS
Normalized to actin
Culture time (days)
d.
TNF-α
Normalized to actin
Cultured time (days)

Figure 2.

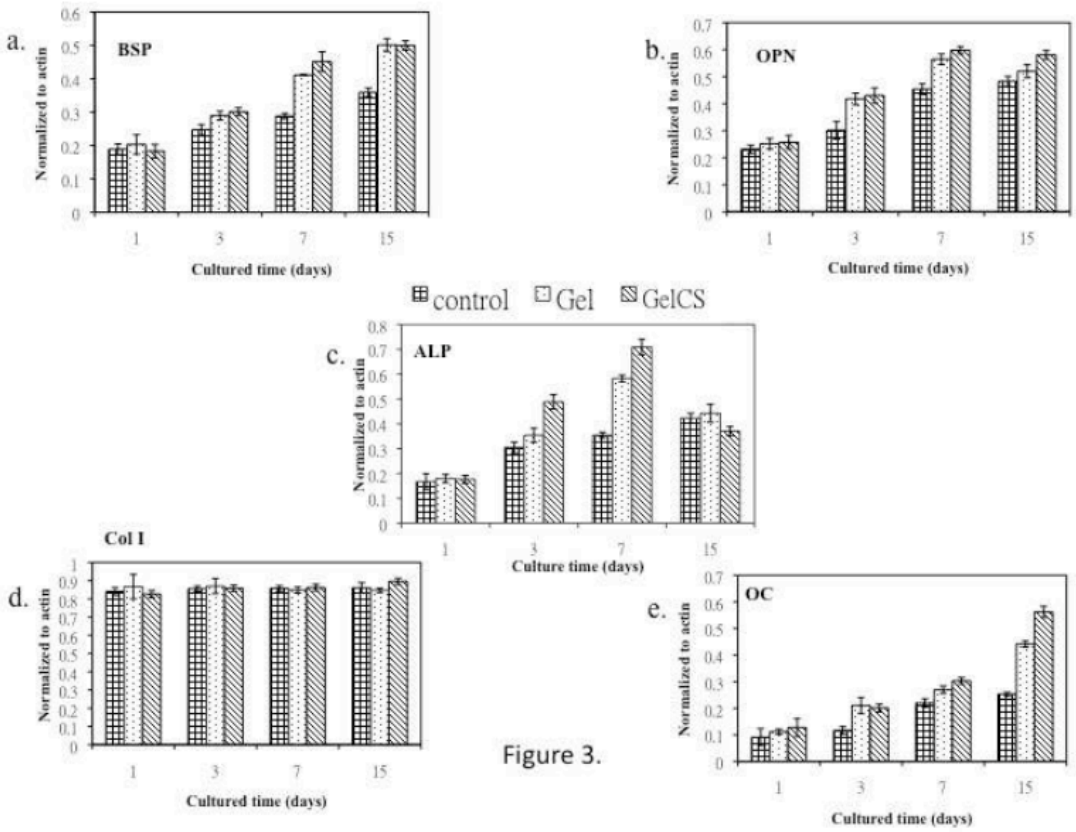
a.
BSP
Normalized to actin
Cultured time (days)
b.
OPN
Normalized to actin
Cultured time (days)
control
Gel
GelCS
c.
ALP
Normalized to actin
Culture time (days)
d.
Col I
Normalized to actin
Cultured time (days)
e.
OC
Normalized to actin
Cultured time (days)

Figure 3.

國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估 □ √達成目標 □ 未達成目標（請說明，以100字為限） □ 實驗失敗 □ 因故實驗中斷 □ 其他原因 說明：
2. 研究成果在學術期刊發表或申請專利等情形： 論文：□已發表 □未發表之文稿 □√撰寫中 □無 專利：□已獲得 □申請中 □無 技轉：□已技轉 □洽談中 □無 其他：（以100字為限） 文章結果以撰寫呈文張章，目前以投稿至雜誌。

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以500字為限）

學術成就：本研究計畫之試驗為過去文獻中未有人執行過之研究，加入明膠作為降解後之支架，概念上應可行，此方式之研究，可以作為學術上研究此類之參考。

技術創新：
本研究技術創新上為將可降解之材料應用於鈣矽類之材料上。

社會影響；
研究結果提供良床上選用材料之另類參考。

國科會補助計畫衍生研發成果推廣資料表

日期:2012/08/16

國科會補助計畫	計畫名稱: 不同成份物質添加於根尖充填材料（矽鈣類合成物)後之生物活性研究
	計畫主持人: 黃翠賢
	計畫編號: 100-2314-B-040-009- 學門領域: 牙醫學

無研發成果推廣資料

100 年度專題研究計畫研究成果彙整表

計畫主持人：黃翠賢	計畫編號：100-2314-B-040-009-
計畫名稱：不同成份物質添加於根尖充填材料（矽鈣類合成物)後之生物活性研究	

成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	1	0	100%	人次	
		博士生	1	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%	章/本	
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（外國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		

其他成果 (無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。)	無

	成果項目	量化	名稱或內容性質簡述
科教處計畫加填項目	測驗工具(含質性與量性)	0	
	課程/模組	0	
	電腦及網路系統或工具	0	
	教材	0	
	舉辦之活動/競賽	0	
	研討會/工作坊	0	
	電子報、網站	0	
	計畫成果推廣之參與（閱聽）人數	0	

國科會補助專題研究計畫成果報告自評表

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1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

■達成目標

□未達成目標（請說明，以 100 字為限）

□實驗失敗

□因故實驗中斷

□其他原因

說明：

2. 研究成果在學術期刊發表或申請專利等情形：

論文：□已發表 □未發表之文稿 ■撰寫中 □無

專利：□已獲得 □申請中 ■無

技轉：□已技轉 □洽談中 ■無

其他：(以 100 字為限)

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）(以 500 字為限)

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社會影響；

研究結果提供良床上選用材料之另類參考。