

**DEVELOPMENT OF FUNCTIONALLY GRADED
COMPOSITE FOR FABRICATION
OF DENTAL POST**

BY

DR. AHMED ABDULLAH ALI MADFA

**DEPARTMENT OF CONSERVATIVE DENTISTRY
FACULTY OF DENTISTRY
UNIVERSITY OF MALAYA**

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Name of Candidate: **Dr. Ahmed Abdullah Ali Madfa** (I.C/Passport No: **2662129**)

Registration/Matric No: **DHA080001**

Name of Degree: **Doctor of Philosophy**

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Name: **Associate Professor Dr. Noor Hayaty Abu Kasim**

Designation: **Associate Professor and Deputy Dean (Research)**

ABSTRAK

Pengenalan: Pada amnya, tiang pergigian seharusnya mempunyai berlainan kekerasan di sepanjang tiang, dimana bahagian hujung korona memerlukan ketegaran yang lebih tinggi bagi pegangan dan ketegaran teras dan nilai ketegaran menurun kearah penghujung apeks. Tujuan kajian ini adalah untuk merekabentuk tiang pergigian yang novel bagi memenuhi keperluan ini. **Objektif:** Kajian yang pelbagai peringkat ini bertujuan untuk merekabentuk, mencari dan mengoptimumkan tiga formulasi novel yang berasaskan komposit berlapisan, bergred dan berfungsi (Functionally graded multilayered composite - FGMC) untuk diaplikasikan sebagai tiang pergigian. Dengan menggunakan FGMC, tiga tiang pergigian bergred dan berfungsi (Functionally graded dental post - FGDPs) dioptimumkan dan dinilai untuk mengkaji taburan tekanan serta tekanan termo-mekanik apabila digunakan sebagai tiang pergigian dalam model gigi incisor maksila yang telah dirawat akar. Akhirnya, rintangan kepatahan dan mod kegagalan tiga FGSPs prototaip ini dibandingkan dengan tiang titanium dan tiang tuangan menggunakan gigi insisor maksila bovin yang telah dirawat akar. **Kaedah:** FGMC telah diproses menggunakan pensinteran tanpa tekanan dan tekanan isostatik panas. Teknik SEM, EDX dan XRD telah digunakan untuk pencirian mikrostruktur dan kerencaman yang diikuti dengan penilaian sifat fizikal dan mekanikal terpilih. Tekanan termo-mekanik di bawah keadaan panas dan sejuk dikaji menggunakan analisis "finite element" (FEA). FEA telah juga digunakan untuk menyiasat taburan tekanan dan ketegangan dalam model gigi, disepanjang bahagian tengah tiang dan di bahagian antara tiang dan struktur sekeliling apabila diberi daya (100 N) di arah menegak, menyerong, dan mendatar. Tiga prototaip FGSPs dengan komposisi yang berbeza; ZrO_2 -Ti-HA, Al_2O_3 -Ti-HA dan Ti-HA telah direkabentuk dan digunakan untuk merestorasikan 30 gigi insisor maksila bovin yang telah dirawat akar. Rintangan kepatahan dan mod kegagalan dinilai dan dibandingkan dengan gigi yang direstorasikan dengan tiang

titanium dan tiang tuangan. Gigi yang normal dan gigi yang hanya dirawat akar tanpa direstorasikan dengan tiang pergigian dijadikan sebagai kumpulan kontrol. **Keputusan:** SEM, EDX dan analisis XRD dari kawasan yang berlainan dalam FGMC mengesahkan elemen yang ada dan perubahan secara beransur-ansur bagi fasa dan elemen Ti-HA-ZrO₂-Al₂O₃. Sifat fizikal dan mekanikal juga berubah secara beransur-ansur mengikut komposisi setiap lapisan, ini mengesahkan bahawa struktur komposit adalah bergred dan berfungsi sebagai satu sistem. Model FGSP jelas mampu mengembalikan suhu hampir ke suhu badan dengan lebih cepat berbanding tiang zirkonia dan titanium dalam jangka masa 5 saat. Magnitud tegasan haba pada tiang dan bahagian struktur sekitarnya adalah lebih besar bagi tiang zirkonia dan titanium terutama sekali di bahagian sepertiga tengah apeks. Tegasan maksima Von Mises, tegasan mampatan dan tegangan serta terikan didapati tertumpu terutamanya di pinggir gigi manakala taburan tegasan ricih pula tertumpu di bahagian antara dentin dan tiang. Tegasan-tegasan Von Mises, mampatan, tegangan dan ricih adalah lebih rendah bagi model FGSP. Tiada perbezaan yang signifikan bagi min rintangan kepatahan antara tiang tuangan (1398.58N ± 314,29), titanium (1408,65 N ± 226,39) dan FGSP (ZrO₂-HA-Ti, 1299.31N ± 251,74; Al₂O₃-HA-Ti, 1242.53N ± 196,55 dan Ti-HA-Ti, 1267.68N ± 173,00). Walau bagaimanapun, tiang tuangan, titanium dan FGSP menunjukkan rintangan kepatahan yang jauh lebih tinggi berbanding dengan kumpulan-kumpulan kontrol. Bagi mod kegagalan pula, hanya kumpulan-kumpulan FGSP dan gigi yang hanya dirawat akar menunjukkan spesimen yang boleh baikpulih dengan peratusan yang lebih tinggi. **Kesimpulan:** FGMC telah berjaya dioptimumkan dan tiga FGSPs prototaip telah direkabentuk. FEA menunjukkan bahawa tiang zirkonia dan titanium menghasilkan tegasan haba yang lebih tinggi berbanding FGSP. FGSP juga menunjukkan tegasan-tegasan Von Mises, mampatan, tegangan dan ricih yang rendah berbanding tiang zirkonia dan titanium. Tiada perbezaan yang signifikan bagi min rintangan kepatahan

FGSP, titanium dan tiang tuangan. Gigi yang direstorasikan menggunakan tiang titanium dan tiang tuangan menghasilkan bilangan gigi patah yang tinggi dan tidak boleh direstorasikan semula, manakala lebih banyak gigi patah boleh direstorasikan semula bagi kumpulan-kumpulan FGSP dan gigi yang hanya dirawat akar.

ABSTRACT

Introduction: Ideally, dental posts should have varying stiffness along its length, where the coronal end require higher stiffness for better retention and rigidity of the core, and this stiffness should reduced towards the apical end. The purpose of this study is to develop a novel dental post that would meet this requirement. **Objectives:** This multi-staged study aimed to fabricating, characterizing and optimizing three novel formulation of functionally graded multilayered composites (FGMC) for possible applications as dental post. Three functionally graded dental posts (FGSPs) derived from optimised FGMC were later evaluated for thermo-mechanical stress and stress distribution when used as dental post in modelled endodontically treated human maxillary incisor. Finally, fracture resistance and failure modes of endodontically treated bovine incisors restored with three FGSPs prototypes were compared to those restored with titanium and cast posts. **Methods:** FGMC were fabricated using pressureless sintering and hot isostatic press. SEM, EDX and XRD techniques were used for microstructural and compositional characterization followed by evaluation of selected physical and mechanical properties. The thermo-mechanical stress under hot and cold conditions was conducted using finite element analysis (FEA). FEA was also used to investigate the stress and strain distributions within the tooth-model, along the centre of the post and at the interface of post and surrounding structures when loaded (100 N) in vertical, oblique, and horizontal directions. Three FGSPs prototypes of different compositions; ZrO_2 -Ti-HA, Al_2O_3 -Ti-HA and Ti-HA were fabricated and used to restore 30 endodontically treated bovine incisors. Fracture resistance and failure modes were evaluated and compared against teeth restored with titanium and cast posts. Sound extracted teeth and endodontically treated teeth without post serves as the control groups. **Results:** SEM, EDX and XRD analyses from different areas of the FGMC confirmed the presence and gradual change of Ti-HA- ZrO_2 - Al_2O_3 elements and phases. The physical and mechanical properties

also changed gradually according to the composition of each layer confirming that the graded multilayered composites structure was functional. It was evident that the FGSP models returned to near body temperature faster than zirconia and titanium posts within the stipulated time frame of 5 seconds. The magnitude of thermal stresses at the post and surrounding structures interface were greater in the zirconia and titanium posts especially at the middle third of the posts. The maximum von Mises, compressive and tensile stresses and strains were mainly concentrated at the tooth periphery while shear stress distributions were primarily located at the post/dentine interface. Lower von Mises, compressive, tensile and shear stresses were observed for FGSP models. There is no significant difference in mean fracture resistance between cast ($1398.58\text{N} \pm 314.29$), titanium ($1408.65\text{ N} \pm 226.39$) and FGSPs ($\text{ZrO}_2\text{-HA-Ti}$, $1299.31\text{N} \pm 251.74$; $\text{Al}_2\text{O}_3\text{-HA-Ti}$, $1242.53\text{N} \pm 196.55$ and Ti-HA-Ti , $1267.68\text{N} \pm 173.00$). However, cast, titanium and FGSP posts showed significantly higher fracture resistance compared to the control groups. For failure mode, FGSPs and endodontically treated teeth only showed higher percentage of repairable failures compared to titanium, cast posts and sound extracted teeth. **Conclusions:** FGMC was successfully optimised and three FGSPs prototypes were fabricated. FEA showed that zirconia and titanium posts produced higher thermal stresses than FGSPs. FGSPs also showed lower von Mises, compressive, tensile and shear stresses compared to zirconia and titanium posts. There was no significant difference in the mean fracture resistance amongst FGSPs, titanium and cast posts. Teeth restored using titanium and cast posts resulted in higher number of non repairable fractures whilst FGSPs and endodontically treated only groups exhibited higher number of repairable fractures.

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DECLARATION

I certify that this dissertation has been based on my own independent work, except where acknowledged in the text or by reference.

No part of this work has been submitted for a degree or diploma to this or any other university.

Dr. Ahmed Abdullah Ali Madfa

Supervised by

Dr. Noor Hayaty Abu Kasim
BDS (Malaya), MSc (Lond), PhD (Newcastle Upon Tyne)
Associate Professor
Department of Conservative Dentistry
Faculty of Dentistry, University of Malaya
Kuala Lumpur, Malaysia

Dr. Mohd. Hamdi bin Abd. Shukor
B. Eng (London), MSc (Manchester), PhD (Kyoto)
Professor
Department of Engineering Design and Manufacture,
Faculty of Engineering, University of Malaya,
Kuala Lumpur, Malaysia

Dr. Reza Rahbari Ghahnavyeh
B. Sci., MSc, PhD (Russia)
Senior Lecturer
Department of Physics,
Faculty of Science, University of Malaya
Kuala Lumpur, Malaysia

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