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APPLICATIONS OF MECHANICAL ENGINEERING IN DENTISTRY

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ABSTRACT
The objectives of the present work are to discuss the role of engineering in developing the instruments applied in root canal therapy. The development includes enhancing the flexibility and elasticity of the materials of files to withstand the stresses that they are subjected to. Based on the research, it was confirmed that the reciprocating motion of files displayed a longer cyclic fatigue life compared to complete rotation. It is proposed to apply single-use files to prevent cross-contamination, where the number of cycles of the files to failure is lower than the limits of cyclic fatigue failure. Besides, the manufacturer of the instruments should supply the users by the specifications of the materials such as the mechanical properties that include tensile and compressive stresses as well as hardness. Finally, further studies are proposed to determine the speed and rotating angles of the reciprocating motions of the endodontic files.

KEYWORDS
Mechanical engineering, dentistry, endodontic files, cyclic fatigue resistance.

INTRODUCTION
It was revealed that nanotechnology, genetic engineering, and ozone therapy will develop dentistry, [1, 4]. Artificial Intelligence (AI) is applied in dentistry in order to diagnose dental diseases and recommend the suitable treatment [5]. The role of AI in dentistry is to analyze the data about certain conditions and advise dental professionals with the required procedures to achieve their work. Using AI systems enables the dentist to do the accurate performance, [6], where the clinical decisions, [7, 8], can be provided by AI software.

Unusual deviations may exist in root canal configuration, [9]. The Cone-beam computed tomography (CBCT) founded the standard for reducing treatment failures resulted from the variations in the morphology of root canal and hence, the clinical

endodontic therapy can be obtained, [10]. The use of CBCT is limited due to its increased radiation dosage, [11]. Besides, AI was applied to display the required data by means of the convolutional neural network (CNN) to assess the variation in root canal anatomy, [12, 13].

There is an increasing demand for integrating engineering in dentistry by instilling the engineering into the procedure of the design of dental restorations and treatments. This can be achieved by introducing the finite element analysis (FEA), where the calculated stresses in FEA can help to modify the type and dimensions of the used material. Besides, it is recommended to apply the engineering basics in the dental restoration to be sure that it conforms not only to the desired shape but also withstands applied load and resists teeth wear. The two items should be covered by intensive study of force and stress analysis as well as the tribological properties of the dental materials. The rapid development in the industry of the biomaterials used in adhesives makes significant change in the form of the dental cavity before restoration and allows many filling materials to be applied. The use of Computer Aided Design (CAD)/Computer Aided Manufacturing (CAM) tools helps dentists to design and manufacture the dental restorations. They are used to mold prostheses and replace the casting process with minimum human error. Besides, these technologies can be employed to develop the accurate orthodontic appliances, [14]. In addition, the development of dental biomaterials to replace and fill bridges as well as crowns showed remarkable progress.

The technology of metal forming is essential in the production of dental restorations. The technology includes extrusion, and forging, [15 - 17]. The structure of metal materials is changing forming affects the plastic deformation and changes the mechanical properties of the materials. In cold deformation, material hardness and strength significantly increase, while toughness and ductility decrease. Cold deformation is accompanied by strain hardening that is essential in dental restorations. Titanium alloys as biocompatible material and widely used in dental restorations are formed in heated process. Powder metallurgy is extensively applied by using materials of micro and nanosized particulate material, [18 - 21].

Wear resistance is a critical property of dental composites resin, [22]. In order to guarantee the curing degree of dental composites it is necessary to test their hardness, [23], where the relatively higher hardness can withstand the abrasion and attrition, [24, 25]. Fibrous materials are extensively used to reinforce the filling materials in dental composites. Glass fibers have relatively higher load transfer and provide high toughness, [26].

Mechanical properties of dental composites such as fracture toughness, compressive strength and hardness were developed by curing and pretreatment of the resin monomers and addition of inorganic fillers, [27 - 29]. The concentration and percent of inorganic the fillers significantly influence the mechanical properties. Recently, nanofibers are used to strengthen dental composites, [30].

Several studies have examined the effect of nanomaterials on the tribological properties of dental composites resin. It was found that titanium dioxide (TiO_2) nanoparticles reinforcing epoxy decreased wear rate, [31, 32]. Addition of silicon oxide (SiO_2) nanoparticles displayed relatively higher hardness wear resistance, [33 - 36].

It was noticed that the hardness, friction coefficient and wear resistance of artificial tooth were affected by the content of the nanofibers. Reinforcing polymethyl methacrylate (PMMA) by silica and zirconia (ZrO_2) nanoparticles increased wear resistance, [37]. Wear resistance of denture teeth is considered as one of the main requirements for oral rehabilitation, [38 - 41]. Denture teeth were made of ceramics, then PMMA was introduced to fabricate the denture teeth, [42 - 45]. Denture teeth based on composite resin were invented to give higher wear resistance and stronger bond to denture bases, [46, 47]. Nano oxide as SiO_2, TiO_2, aluminum dioxide (Al_2O_3), silicon nitride (Si_3N_4), and ZrO_2 were tested as the filling materials of PMMA to enhance the tribological properties, [48 - 50].

Application of engineering in the field of biology and medicine is called biomedical engineering, [51]. Because dentistry needs the technical instruments, it is necessary for biomedical engineering to be involved in dentistry through advanced researches to develop the tools and materials for diagnosis and treatment. Several inventions in dentistry such as computer assisted design (CAD), computer assisted manufactured (CAM) are applied to enrich the field of dentistry, [52, 53].

Dental practitioners commonly face two important things throughout their professional life. These are tooth decay and periodontal disease, [54]. The complex natures of these diseases occur due to bacterial, genetic and environmental factors. Using the polymerase chain reaction (PCR) brings out a remarkable change in dentistry to diagnose periodontal diseases, [55]. PCR in dentistry can detect the presence of viruses in host cells and the microorganisms in endodontic infections. In addition, it reveals diagnosis and prognosis of oral cancer. Biomedical engineering technology are applied in tissue and bone regeneration, [56].

The objective of the present study is to focus the role of engineering in developing the endodontic instruments. During the preparation of root canal, the endodontic instruments are subjected to stresses such as bending, torsion, compression and tension. As a result, these instruments require enough flexibility and elasticity to overcome the stresses for a long time. The materials of the endodontic instruments made of nickel-titanium alloys (NiTi) replaced the stainless-steel to fulfil the required performance, [57, 58].

DISCUSSION

Mechanical engineering has been involved in the testing of cyclic fatigue resistance of the endodontic rotary instruments. Several instruments and procedures have been used to investigate the cyclic fatigue resistance of NiTi endodontic instruments. Besides, force and stress analysis were utilized to evaluate the performance of the instruments and procedures, [59 – 68]. In addition, the kinematics of movement of

rotary file were investigated, [69 - 72], where reciprocation motion in endodontics was introduced instead of the complete rotation. It was found that, the reciprocating movement gave relatively longer cyclic fatigue life of the F2 ProTaper instrument compared to the complete rotation, [75].

The continuous repetitive bending stress leads to the failure of the element subjected to the stress. It was observed that fatigue failure is initiated by the surface microcracks that grow as the loading cycle increases, [76]. It is known that tensile stress causes surface cracks that propagate in instrument and induces zone of concentrated stresses, [77]. It was observed that failure of endodontic files resulting from the residual stresses, [78, 79]. As a result of that, the fatigue life of the files can be considered as a function of the tensile value and the size and number of cracks initiated on the surface. It was recommended that reciprocating motion can develop the mechanical properties of the files and enhance fatigue resistance, in comparison of continuous rotation, [80, 81]. To evaluate the different reciprocating motions including rotating angles and speed, it is necessary to perform extra research to determine the optimal motion for treatment of root canal. It was proposed that single-use files can be used in order to prevent cross-contamination, [81], fatigue resistance does not influence the clinical situations because the number of cycles of the files is relatively lower than the limits of cyclic fatigue failure. Besides, the materials of the files used in the removal of endodontic filling material should be developed by enhancing the efficiency of cutting and cleaning the root canal to save the time and the fractured files, [82, 83].

CONCLUSIONS

The present study evaluated the development of the instruments used in root canal therapy. It can be concluded that improving elasticity and flexibility of the materials of files to withstand the stresses is critical. It was approved that reciprocating files showed longer cyclic fatigue life compared to rotating ones. To increase the mutual cooperation between the dentist and manufacturer of the instruments, the mechanical properties of the materials such as tensile and compressive stresses as well as the hardness should be certified. Finally, further studies are proposed to determine the speed and rotating angles of the reciprocating motions of the endodontic files. In the field of the removal of endodontic filling material, it is recommended to introduce efficient retreatment system to make the removal of the filling materials of root canal consuming less time and lower number of fractured files.

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