

THE COMPARISON OF DIFFERENT THICKNESSES OF RESIN COMPOSITE FILLING FOR REST SEATS IN DISTAL EXTENSION REMOVABLE PARTIAL DENTURES: A FINITE ELEMENT ANALYSIS

Trust SAWAENGCHAROEN¹, Sukontip ARWATCHANAKAN¹,
Pongsakorn POOVARODOM² and Yotsakorn PRATUMWAN³

1 Faculty of Dentistry, Khon Kaen University, Thailand

2 James B. Edwards College of Dental Medicine, Medical University of South Carolina, USA.

3 National Metal and Materials Technology, Thailand

ABSTRACT

The objective of this research was to evaluate the effect of resin composite thickness for rest seats in distal extension RPD on mechanical behavior by finite element analysis. The results of the study revealed that: 1) The maximum von Mises stress within the resin composite was comparable regardless of thickness 2) Thickness affected maximum von Mises stress within abutment tooth and RPD framework 3) Fatigue analysis indicated that all models successfully endured up to 1×10^8 loading cycles regardless of the rest seat thickness. Conclusion: 1) Resin composite exhibited sufficient mechanical strength and fatigue resistance to serve as a reliable rest seat material for removable partial denture. 2) Resin composite rest seat at a thickness of at least 1.0 mm is recommended for abutment tooth.

Keywords: Rest Seat, Resin Composite, Removable Partial Denture, Finite Element Analysis

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INTRODUCTION

A removable partial denture (RPD) is commonly used in partial edentulism (Ting-Ling et al., 2019). Occlusal rest plays a major role in providing vertical support for RPD and distributing the masticatory force through the long axis of abutment teeth (Zarb B, 2013). An occlusal rest should be prepared on sound tooth enamel or restorations (McCracken, 2004). Over the past few decades, the use of resin composite as a restorative material has increased due to its esthetic tooth color, acceptable strength, ease of use for practitioners, and metal-free composition (Burke, 2004). However, fracture is the most common cause of failure in resin composite restorations, and resin composite thickness affects compressive strength and fatigue resistance (da Rosa Rodolpho et al., 2006; Hamburger et al., 2014; Schlichting et al., 2011). To withstand the occlusal force, the mechanical behavior, particularly fatigue properties, should be considered for rest seat material selection (Zhou et al., 2019). Nonetheless, the study investigating the fatigue behavior in different thicknesses of resin composite used to restore occlusal rest for RPD remains limited. Nowadays, 3D finite element analysis (FEA) has been introduced in the field of dentistry and has been claimed to be suited for the examination of the structural behavior of the oral cavity (Desai & Shinde, 2012). Therefore, the purpose of this study is to evaluate the effect of the thickness of resin composite on stress distribution, maximum stress, and fatigue lifetime of resin composite used to restore occlusal rest seats for RPD using finite element analysis (FEA).

LITERATURE REVIEW

When considering the support, RPD can be classified into two groups. Tooth-supported RPD is supported by periodontal ligaments of abutment teeth, but support in tooth-tissue-supported RPD is provided from both the more stable teeth and the resilient and displaceable underlying ridge tissue (McCracken, 2004). Because of two different supports, distal-extension RPD (one type of tooth-tissue-supported RPD) tends to be challenged with excessive pressure. These not only directly damage the tissue, resulting in residual ridge resorption, but they also indirectly transmit the load and may cause tilting of the abutment tooth. (Krol, 1973; Nairn, 1966). A distal extension RPD with a distal rest and a wrought wire clasp can reduce mechanical stress on the supporting abutment teeth. Although this design functions as a class I lever, the flexibility of the wrought wire functions as a stress-breaker that diminishes the transmission of torquing forces to the abutment tooth and its surrounding structures. (Sukapattee, 2022)

Occlusal rest is a rigid extension of RPD that contacts the prepared rest seat on the abutment tooth. It plays a major role in providing vertical support for RPD and distributing the masticatory force through the long axis of abutment tooth. Occlusal rest seat should be saucer or spoon shape with buccolingual width of 2 mm to half of inter-cuspal distance, mesiodistal length of one third to one half of the crown, and the thickness of 1.0 to 1.5 mm (Sato et al., 2003).

Occlusal rest seat should be prepared on sound tooth enamel or restorations to withstand the occlusal force (McCracken, 2004). Although indirect restorations may have more longevity, direct restorations continue to be the alternative choice because of the lower need for sound tooth removal. Advances in direct materials technology have increased materials survival, and the low cost of direct restorations compared to indirect ones (Correa et al., 2012). Over the past few decades, the use of resin composite as a restorative material has increased due to its esthetic tooth color, acceptable strength, ease of use for practitioners, and metal-free composition (Burke, 2004). Resin composite can be used to restore the occlusal rest seat since it is more resistant to compressive strength than tensile strength and its action is similar to the cushion beneath the occlusal rest by absorbing the applied load and cusp reinforcement provided by bonding to the tooth structure (Tihaček-Šojić et al., 2011). Filtek Z250 is a micro-hybrid composite, designed for use as a direct posterior restoration, which is usually used in many

laboratory tests. According to the previous study that investigated the mechanical properties of various types of resin composites, Filtek Z250 showed the highest values on compressive and flexural strength (Abuelenain et al., 2015). Therefore, resin composite may be considered as an alternative rest seat material

Finite element analysis (FEA) was used to simulate RPD, including the rest seat, to evaluate the biomechanical behavior of the RPD and supporting structures (Tihaček-Šojić et al., 2011). When FEA is performed, it is unnecessary to fabricate real models, and any parameters are easily modifiable (Sato et al., 2003). The previous study reported that the fatigue resistance results of laboratory testing and FEA were comparable (Vanichanuwat & Wongchuensoontorn, 2020). Nowadays, 3D FEA has been introduced in the field of dentistry and has been claimed to be suited for the examination of structural behavior of the oral cavity. including RPD and supporting structures

Hypothesis

The thickness affects the fracture resistance of resin composite rest seat in distal extension removable partial denture.

RESEARCH METHODOLOGY

This study is an *in silico* analysis using finite element analysis. The 3D model of the lower left second premolar was created using 3D CAD design software (SolidWorks 2017). The disto-occlusal surface of the premolar abutment was prepared for a class II resin composite restoration. The cavity thicknesses were 2.0, 2.5, and 3.0 mm, with a mesiodistal distance of 3.5 mm and a buccolingual distance of 4 mm. The resin composite models were created to conform to the cavities of abutment tooth models. Occlusal rest seats were prepared on the occluso-distal surface of the resin composite model with the same dimensions in all models. Floor of rest seats were saucer or spoon-shaped, with a thickness of 1.0 mm. From the occlusal view, a rest seat was a triangular shape with the tip turning to center of the tooth model with a 2.5 mm mesio-distal length and 2.0 mm bucco-lingual width. After preparation, the vertical thicknesses of the remaining resin composite were 1.0, 1.5, and 2.0 mm, with a periphery thickness of 1.0 mm surrounding the rest seat. Finally, the prepared premolar abutment models with three different thicknesses of resin composite rest seats were provided.

A unilaterally partial edentulous mandibular model (Kennedy classification I) was composed of the premolar abutment tooth models with a prepared rest seat and the supporting structures. Cortical and cancellous bone were constructed around the abutment tooth, with the bone level 2 mm below the cemento-enamel junction (CEJ). Periodontal ligament space was 0.2 mm at root surfaces of abutment teeth, and Mucosa thickness at edentulous area was 2 mm.

Occlusal rest connecting from the minor connector was designed to conform to the prepared occlusal rest seat on the abutment teeth. The retentive frameworks and proximal plates were also created. Digital denture teeth of the lower first and second molars were arranged in the RPD. Denture base and wrought wire clasp were created to complete the morphology of RPD Models of tooth-tissue-supported RPD on free-end partial lower arch with different thicknesses of resin composite were obtained (Figure 1). All models were saved in Parasolid files and then exported to 3D Simulation software (ANSYS). Model meshing was performed by locating nodes and elements. All elements are assumed to be homogeneous, linear elastic and isotropic. To verify the reliability of the finite element results, a mesh independence study was performed. The mechanical properties of materials (Kanbara et al., 2012; Morris & Asgar, 1975) and coefficients of friction of materials (Mahmood S, Ali G, Shakoor A, 2002; Pancote J, de Castro DT, 2014) were defined (Table 1,2).

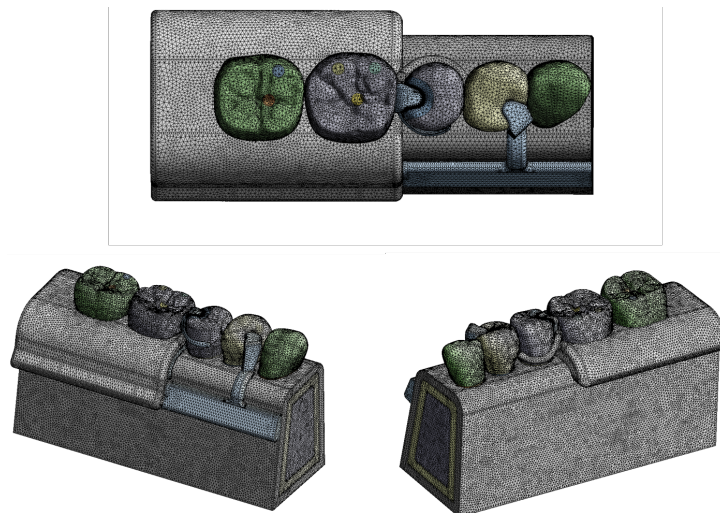


Figure 1 Model of distal-extension RPD with a distal rest and wrought wire clasp

Table 1 Mechanical properties of materials

Material	Young's modulus (GPa)	Poisson ratio
Enamel	41.4	0.35
Dentine	18.6	0.35
Resin acrylic and artificial teeth	2.45	0.30
Co-Cr Alloy	218	0.33
Stainless steel wrought wire	200	0.30
Cortical bone	11.76	0.25
Sponge bone	1.47	0.30
Gingiva	0.0196	0.30
Periodontal ligament	0.1	0.45
3M Filtek Z250	18.7	0.31

Table 2 Coefficient of friction of materials

Material Pair and Condition	Typical μ (Static)	Typical μ (Kinetic)
RPD rest (Co-Cr) on resin composite	0.15	0.08
RPD framework (Co-Cr) on tooth (enamel)	0.20	0.12
RPD baseplate (Acrylic resin) on oral mucosa	0.15	0.02
Wrought wire on tooth (enamel)	0.15	0.08
Tooth (enamel) on tooth (enamel)	0.31	0.26

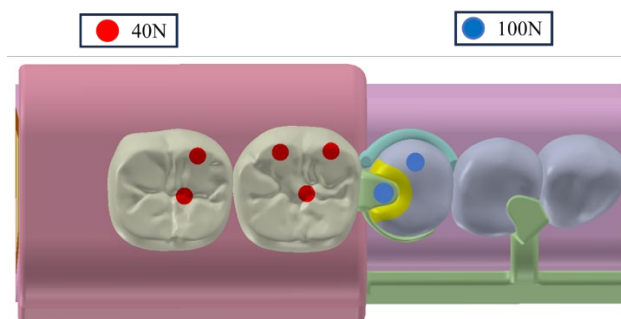


Figure 2 Loading points and magnitudes on posterior teeth

A unilateral static loading condition was performed to evaluate stress distribution. The magnitudes of the forces, as well as the acting point, were determined employing the previous

reports (Benazzi et al., 2014; Nakamura et al., 2014) (Figure 2). Five vertical loads of 40N were applied to the denture molar teeth. Two points at the buccal cusp and one point at the central pit of the first molar, and two points at the mesio-buccal cusp and central pit of the second molar resulted in total applied loads of 200N. The premolar abutment was also subjected to two loads of 100N each, which was total of 200N.

Goodman and Gerber fatigue theories were used to calculate alternating stress, and then was plotted in S-N curves (which showed fatigue properties of materials in terms of alternating stress versus the number of cycles) to evaluate the fatigue lifetime of materials (Lohbauer et al., 2013).

Goodman's formula

$$\frac{\sigma_a}{S_e} + \frac{\sigma_m}{S_u} = \frac{1}{N}$$

Gerber's formula

$$\frac{N\sigma_a}{S_e} + \left(\frac{N\sigma_m}{S_u}\right)^2 = 1$$

N indicated the safety factor for fatigue life in loading cycle, S_e for endurance limit, and S_u for ultimate tensile strength of the material. Mean stress (σ_m) and alternating stress (σ_a) were defined respectively as

$$\sigma_m = \frac{\sigma_{max} + \sigma_{min}}{2}$$

$$\sigma_a = \frac{\sigma_{max} - \sigma_{min}}{2}$$

Maximum von Mises stress (σ_{max}) and minimum von Mises stress (σ_{min}) were used to calculate for mean stress (σ_m) and alternating stress (σ_a).

RESEARCH RESULTS AND DISCUSSION

The maximum von Mises stresses observed within resin composite rest seat, abutment tooth, and RPD across the three thickness variations (1.0, 1.5, and 2.0 mm) were summarized in Table 3. Stress analysis showed maximum von Mises stress levels within resin composite rest seat were comparable across all thicknesses. Models of 1.0 mm, 1.5 mm, and 2.0 mm recorded maximum values of 59.79, 59.50, and 59.67 MPa, respectively. These results are consistent with a previous 3D finite element study, which revealed comparable maximum von Mises stress values ranging from 56.8 to 78.4 MPa (Paruchuri et al., 2025). These findings indicate that alterations in composite thickness had no significant impact on peak stress levels. Stress concentrations were primarily localized at the center of the rest seat floor and dissipated radially toward the periphery (Figure 3). While occlusal forces are primarily compressive, the rest seat geometry and RPD design generate bending and tensile stress (Uchikura et al., 2022). Furthermore, resin composites are inherently brittle and are significantly weaker under flexural and tensile forces than under pure compression (Feiz et al., 2016). Consequently, flexural strength serves as a highly reliable metric for predicting material failure under complex loading conditions. In the present study, the maximum von Mises stress remained below the established flexural strength range of the Filtek Z250 composite (160 MPa) (Kumar et al., 2018). This indicates that the applied loads are unlikely to cause mechanical failure in the restorative material of resin composite.

To evaluate the long-term durability of resin composite rest seats, von Mises stresses were analyzed using Goodman's and Gerber's equations, with safety factors of 1.43 and 1.76, respectively. Furthermore, the fatigue analysis indicated that all models successfully endured up to 1×10^8 loading cycles, regardless of the rest seat thickness. These predictive loading cycles demonstrate exceptional longevity, exceeding comparable findings in existing literature, which reported a survival rate of 1.16×10^6 cycles (Farzin et al., 2014) and other in vitro study evaluating resin materials up to 3.7×10^6 cycles (Aboushelib & Elsafi, 2016). Since an average person performs about 250,000 chewing cycles per year, enduring 1×10^8 cycles theoretically

equals 400 years of clinical function (DeLong & Douglas, 1991). Supported by safety factors greater than 1.0, these findings theoretically assume that resin composite possesses an infinite fatigue life, meaning it can endure these specific cyclic forces without undergoing catastrophic fatigue failure from these applied mechanical forces (Darwich et al., 2023). It is important to note that this extended theoretical longevity solely reflects resistance to isolated mechanical loading and does not account for the multifaceted causes of clinical failure. In the actual oral environment, restorations typically fail due to biological or chemical factors, such as secondary caries, adhesive degradation, or material wear, rather than pure mechanical fatigue (De Munck et al., 2005). The findings of this study do not support the hypothesis that thickness affects the fracture resistance of the resin composite rest seat in a distal extension RPD. As the maximum von Mises stress levels remained comparable across the 1.0 mm, 1.5 mm, and 2.0 mm models, no significant thickness-dependent effect was observed within resin composite.

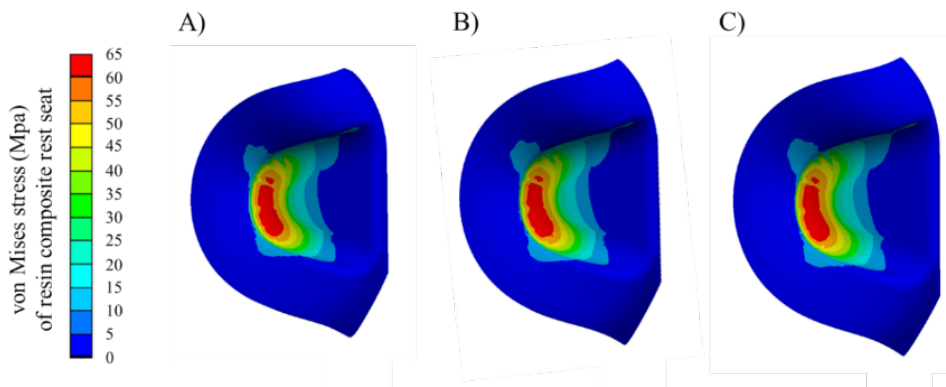
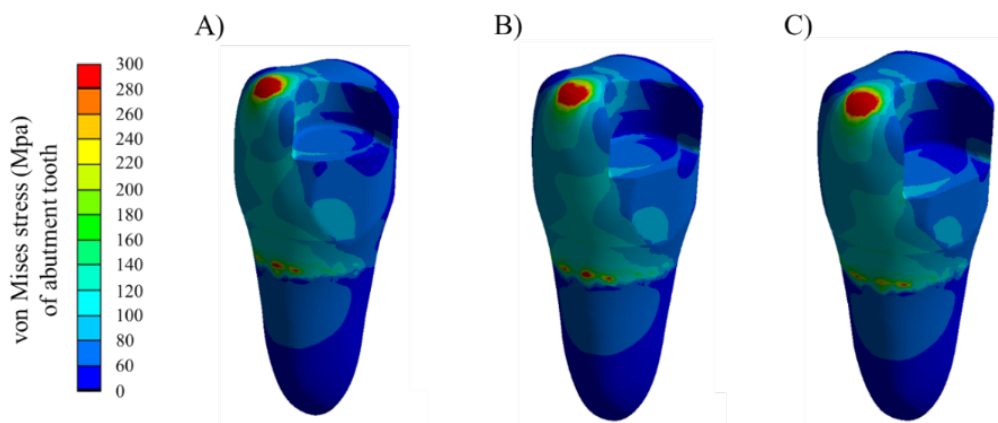
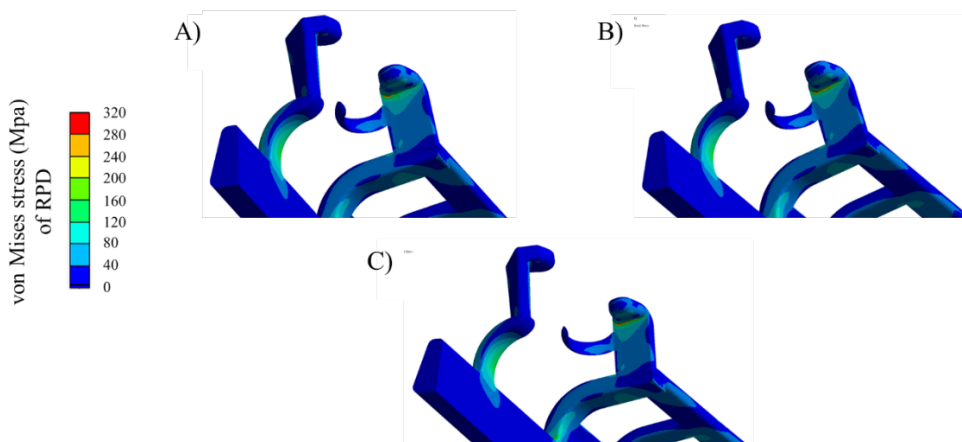
An inverse relationship was observed between the thickness of resin composite rest seat and the stress occurring on the abutment tooth. As the thickness increased from 1.0 to 2.0 mm, von Mises stress decreased from 291.78 to 230.75 MPa. Stress concentrations localized at the load application area on the buccal cusp, dissipated apically, and subsequently re-amplified at the cemento-enamel junction (CEJ) (Figure 4). This indicates that a thicker resin composite acts as a more effective shock absorber or stress distributor, protecting the underlying dentin and enamel from the applied force (Yamanel, K., Çelik, C., Gökçe, 2009). These results are consistent with previous biomechanical studies, which confirm that increasing restorative volume significantly lowers stress. Lyu demonstrated that greater thickness minimizes stress concentrations at the tooth-restoration interface (Lyu et al., 2022). Similarly, Ausiello found that restorations of 2.0 mm or more reduce stress at the cavity floor by 30 to 40% compared to thinner layers of 1.0 mm or less (Ausiello et al., 2011). Although the peak von Mises stress reached 291.78 MPa, it was predominantly compressive in nature, which remains below the ultimate compressive strength of enamel (400 MPa) (Dejak & Bołtacz-Rzepkowska, 2023). Therefore, catastrophic structural failure is unlikely under normal loading conditions.

Conversely, within the RPD framework, higher maximum stress values were generally associated with greater rest seat thickness. The peak stress concentrations for the 1.5 mm and 2.0 mm models were comparable (319.87 and 313.05 MPa, respectively), both exceeding the 1.0 mm model (299.77 MPa). These peak stresses were primarily localized at the junction between rest and proximal plate of RPD framework, dissipating radially toward the peripheral regions (Figure 5). Although thicker composite rest seats protect the abutment tooth, they create a biomechanical trade-off by increasing stress within the RPD framework. The thicker resin composite acts as a flexible cushion, allowing the metal rest to flex more during occlusion (Ausiello et al., 2011). This increased bending movement resulted in peak stresses. The stress concentrated primarily at the junction of the occlusal rest and the proximal plate, which served as a fulcrum, consistent with the previous study (Sato et al., 2003). However, the values recorded in the RPD framework remain within the yield strength of RPD alloys, which typically exceeds 500 MPa, ensuring the alloy can safely withstand applied forces without risking permanent deformation (Wu et al., 2014).

The relative amounts of enamel and dentine remaining after cavity preparation played a crucial role in clinical decision-making. A thicker rest seat requires invasive preparation that removes a larger amount of tooth structure, increasing the biological risk of pulpal irritation (Magne et al., 2015). From these data, a 1.0 mm resin composite thickness is recommended.

Table 3 Maximum von Mises stress for varying thickness of resin composite rest seat

Element	Maximum von Mises stress (MPa)		
	1.0 mm	1.5 mm	2.0 mm
Composite rest seat	59.79	59.50	59.67
Abutment tooth	291.78	252.84	230.75
RPD	299.77	319.87	313.05

**Figure 3** Von Mises stress within resin composite rest seat: A) 1.0 mm, B) 1.5 mm, and C) 2.0 mm**Figure 4** Von Mises stress distribution within abutment tooth: A) 1.0 mm, B) 1.5 mm, and C) 2.0 mm**Figure 5** Von Mises stress distribution within RPD framework: A) 1.0 mm, B) 1.5 mm, and C) 2.0 mm

LIMITATIONS

While this FEA provides valuable predictive insights, several limitations must be acknowledged. The computational model assumed that the abutment tooth and resin composite were isotropic, homogeneous, and linearly elastic, whereas natural teeth are complex, anisotropic, and viscoelastic structures. Additionally, the adhesive interface was idealized as a perfectly bonded union, which does not account for clinical realities such as polymerization shrinkage, nano-leakage, or hydrolytic degradation over time. Furthermore, the simulated loading conditions simplified the complex, multi-directional forces of natural mastication and excluded the dynamic intraoral challenges of thermal cycling, pH fluctuations, and enzymatic activity (Lima et al., 2022). Consequently, future in vitro mechanical testing and long-term in vivo clinical trials remain essential to fully validate the functional survivability of these resin composite rest seats under true clinical conditions.

CONCLUSION

Within the limitations of this three-dimensional finite element analysis, the following conclusions can be drawn:

- 1) Resin composite exhibits sufficient mechanical strength and fatigue resistance to serve as a reliable rest seat material for removable partial denture.
- 2) Resin composite rest seat at a thickness of at least 1.0 mm is recommended for abutment tooth

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Data Availability Statement: The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Conflicts of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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