Research Article

BIOMEDICAL Journal of Scientific & Technical Research

ISSN: 2574 -1241

DOI: 10.26717/BJSTR.2022.44.007075

Comparison of Two Types of Dual Resin Cements in Cantilever Dental Bridge Compressive Stress Distribution: Finite Element Analysis

Angeles Maslucan Romy[1]*, Chavez Mendez Martin[2] and Martinez Aparcana Danna[2]

[1]*Faculty of Stomatology, Universidad Peruana Cayetano Heredia, Peru*

[2]*Faculty of Life Sciences and Health, School of Dentistry., Universidad Científica del Sur, Peru*

***Corresponding author:** Angeles Maslucan Romy, Faculty of Stomatology, Universidad Peruana Cayetano Heredia, Lima, Peru

ARTICLE INFO

Received: June 04, 2022

Published: June 16, 2022

Citation: Angeles Maslucan Romy, Chavez Mendez Martin and Martinez Aparcana Danna. Comparison of Two Types of Dual Resin Cements in Cantilever Dental Bridge Compressive Stress Distribution: Finite Element Analysis. Biomed J Sci & Tech Res 44(4)-2022. BJSTR. MS.ID.007075.

ABSTRACT

Context: The resin bonded fixed dental prostheses are a conservative restorative treatment, used mainly to replace missing teeth in the anterior sector. In this type of prosthesis, the selection of the cement is important because, according to the literature, the most frequent cause of its failure is detachment (33.7%); however, only few studies consider this factor.

Aims: Compare the compressive stress distribution generated in a cantilever bridge when using two types of dual resin cements, through finite element analysis.

Material and Methods: Two virtual models were designed using SOLIDWORKS® software version 2017. In both models, a cantilever was simulated with a pontic (lateral incisor) and a palatal retainer (upper left canine). Relyx U200 cement was used in model A and Relyx ARC cement in model B. Then, a force of 100 Newtons (N) was simulated on the palatal side of the pontic at an angle of 45° and a horizontal force of 100N on the palatal side of the canine.

Results: For both models, the maximum stress was 660.891 MPa when applying oblique forces and 16.6 MPa when applying horizontal forces. Regarding the displacement, the maximum value was 0.014 mm for oblique forces and 0.00066 mm for horizontal forces.

Conclusion: The results were the same for both models, where it was observed that the compressive stress values were higher when applying oblique forces compared to horizontal forces.

Keywords: Finite Element Analysis; Cantilever; Dual Resin Cements

Introduction

Nowadays, it has become common to find young patients with missing teeth [1]. In these cases, dental implants are the first option [2], since they have a high success rate (94%) [3] and allow aesthetically pleasing results to be achieved [4]; however, it is an expensive treatment [5]; therefore, as an alternative, the resin-bonded fixed dental prostheses (RBFDP) can be used [6]. The latter is characterized by the fact that, unlike the conventional fixed prosthesis, it requires a more conservative wear of the surface of the abutment teeth [7]; in addition, it is economical compared to the implant [5]. RBFDPs began to be known in the world of dentistry in the 1970s [8] and their design evolved over time [6]. Within this group, we can mention the Maryland bridge, [6] which was created by professors from the university of the same name [9] and its main characteristic is to have two palatal retainers; There is also the cantilever, whose peculiarity is based on the possession of a single palatal retainer [6]. Currently, they are used to replace missing teeth in the anterior sector [10]; however, at some point an attempt was made to extend their indication to the posterior sector [11], but several investigations have shown unfavorable results [12]. There are studies that have compared the success of the Maryland bridge and the cantilever in the anterior sector, where the latter demonstrated more satisfactory results [13]. This is because the teeth in that area they receive forces in different directions during chewing; therefore, in the case of the cantilever, the pontic is free to move in the same direction as the retainer [13].

The union of the adhesive fixed prosthesis is mainly based on adhesion [6]; for this reason, the choice of cement is important. This is evidenced in a variety of systematic reviews, where it is detailed that the most recurrent cause of failure for this type of prosthesis is detachment (33.7%) [14]. Likewise, masticatory force is a factor that should be consider when choosing the cement, because, during chewing, different types of forces are exerted [15], which can cause disunion between the prosthesis and the tooth. There are few studies that have evaluated the distribution of compressive stresses in RBFDP when using different types of cements through finite element analysis, [2,16,17] despite being a useful tool for this purpose. This method allows the evaluation of the mechanical properties of structures such as fixed prostheses or implants [18] through the use of irregular geometry solids software, isolating the variable of interest from various external factors that may affect the result.16 In turn, it is widely used in the area of dentistry since, unlike other experimental studies, it is precise, easy to perform and requires less time [19]. Therefore, the purpose of this study was to compare the distribution of compressive stresses in a cantilever bridge using two different types of dual resin cement, designed through finite element analysis.

Materials and Methods

This research was approved by the Research Ethics Committee of the Universidad Cientifica del Sur, with the approval code 521-2021-PRE8. The models were built following these steps: first, the construction of the models was carried out, then the forces were applied and at the end, the results were analysed. Two virtual models were designed using SOLIDWORKS® software version 2017 (SolidWorks Corporation, France), which consisted of a central incisor and an upper left canine, fixed on a surface. In both models, a lithium disilicate cantilever bridge was simulated with a pontic (lateral incisor), a palatal retainer (upper left canine) and a 16mm2 connector [20]. The difference between both models was the dual resinous cement, since Relyx U200 cement was used in model A and Relyx ARC cement in model B. For both models, a 1mm preparation was made in the centre of the palatal aspect of the upper left canine, covering only enamel to be conservative, with a supragingival termination line. The cement layer was patterned with a uniform thickness of 0.1mm. The mechanical properties that were considered in the study are the modulus of elasticity and the Poisson's ratio, which were summarized in Table 1 [17,21-23]. Finally, a force of 100N was applied to the palatal aspect of the lateral incisor (pontic) at 2mm below the incisal surface of the tooth, at an angulation of 45° and a horizontal force of 100N on the palatal aspect of the canine, simulating the direction of forces that this sector receives. After all this, the results of the stress fields and displacement of the evaluated prosthesis were obtained. These data were obtained through Von Mises stress analysis, whose criterion is based on the conception of internal energy.

Table 1: The mechanical properties of the materials used in this study

Material	Modulus of Elasticity (MPa)	Poisson's Ratio
Enamel	84100	0,33
Dentine	18600	0,32
Pulp	2.1	0.45
Relyx U200 cement	6600	0,33
Relyx ARC cement	5100	0,27
Lithium disilicate	95000	0.25

Results

Table 2: Results of the compressive stress distribution (MPa) in a prosthesis cemented with Relyx U200.

	Oblique Forces	Horizontal Forces	
	Maximum Value	Maximum Value	Minimum Value
Cantilever bridge	660.891	16.6	4.22e-06

Table 3: Results of the compressive stress distribution (MPa) in a prosthesis cemented with Relyx ARC.

	Oblique Forces	Horizontal Forces	
	Maximum Value	Maximum Value	Minimum Value
Cantilever bridge	660.891	16.6	4.22e-06

Note: Maximum value (maximum peaks of compressive stress).

The results can be seen as colorimetric graphs in megapascals (MPa) scale for compressive stresses and in millimetres (mm) for

 DOI: 10.26717/BJSTR.2022.44.007075

displacement. Likewise, in tables it can be analysed that both the compressive stresses (Tables 2 & 3) and the displacement (Table 4) for both models followed the same pattern after the loads were applied. Regarding the compressive stress calculated in the prosthesis that was cemented with Relyx U200 dual resin cement (Table 2), higher stress values were observed when applying oblique forces (660,891 MPa) compared to horizontal forces (16.6MPa) (Figures 1 & 2). The same happened with respect to the compressive stress calculated in the prosthesis that was cemented with Relyx ARC dual resin cement (Table 3), where higher stress values were also produced when applying oblique forces (660,891MPa) (Figures 3 & 4). Regarding the displacement of the cantilever bridge (Table 4), the same results were obtained in both models, where it was greater when receiving oblique forces (0.014mm) compared to horizontal forces (0.00066mm) (Figures 5 & 6); however, in both cases, the values obtained were minimal (Table 4).

Table 4: Comparison of displacement of the cemented cantilever bridge with Relyx U200 (Model A) and Relyx ARC (Model B).

	Oblique Forces		Horizontal Forces	
	Maximum Value	Minimum Value	Maximum Value	Minimum Value
Model A	0.014mm	1e-030mm	0.00066mm	1e-030mm
Model B	0.014mm	1e-030mm	0.00066mm	1e-030mm

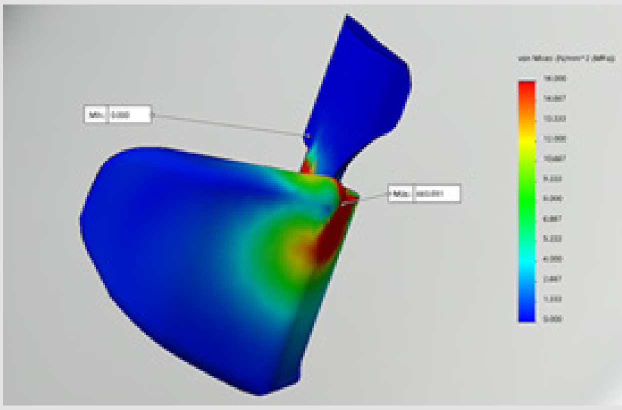

Figure 1: Results of the compressive stress distribution in a prosthesis cemented with Relyx U200 after the application of oblique forces of 100N.

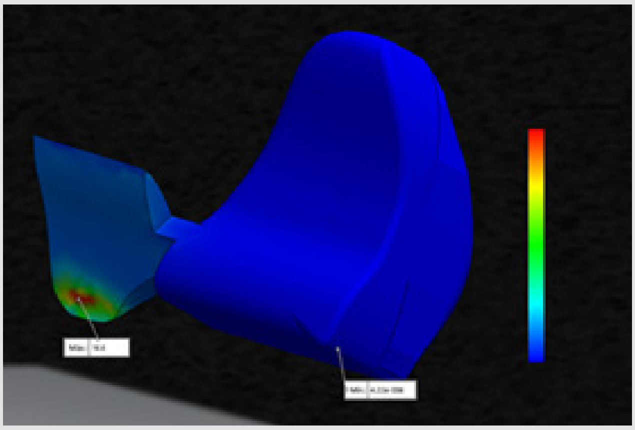

Figure 2: Results of the compressive stress distribution in a prosthesis cemented with Relyx U200 after the application of horizontal forces of 100N.

Discussion

The analysis of both models when applying oblique forces, showed that the maximum stress in the prosthesis was located at the level of the pontic and on the incisal edge adjacent to the pontic. This result agrees with other studies such as that of Uraba A, et al. [24] where they evaluated 3 models of fixed adhesive zirconium prostheses in the anterior sector by means of a finite element analysis and obtained as a result that, in all the models, the maximum stress concentrated on the incisal side of the connector, applying a force of 200N at 45° from the pontic. Likewise, Wei Y, et al. [25] in their systematic review on the failure and complication rate

DOI: 10.26717/BJSTR.2022.44.007075

of different adhesive fixed prosthesis designs in the anterior sector, recommended that a larger dimension connector should be used to improve the properties of the material in that area. Regarding the displacement of the prosthesis, the results obtained support the study by Keulemans F, et al. [26], who carried out a finite element analysis comparing five cantilever bridges made of different materials, including vitrioceramic and zirconium, obtaining as a result a greater displacement of the prosthesis in the pontic part when applying a stress of 90MPa, at an angle of 45° to the incisal edge of the pontic. In addition, the homogeneity of the results of the present investigation agrees with the finite element study by Penteado M, et al. [2], who compared six types of cements with different modulus of elasticity and observed that the displacement pattern was the same for all the models evaluated.

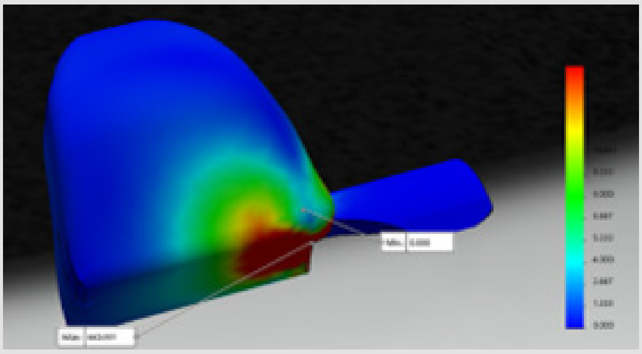

Figure 3: Results of the compressive stress distribution in a prosthesis cemented with Relyx ARC after the application of oblique forces of 100N.

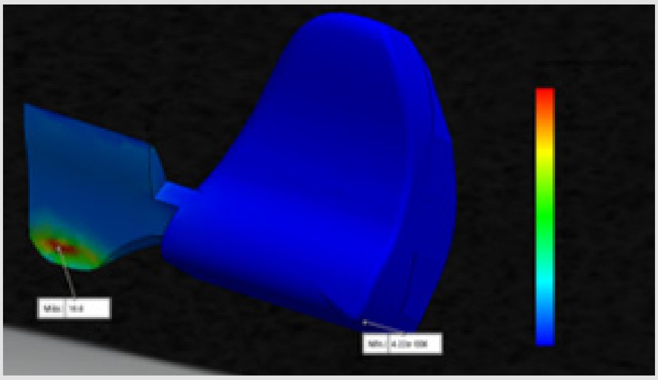

Figure 4: Results of the compressive stress distribution in a prosthesis cemented with Relyx ARC after the application of horizontal forces of 100N.

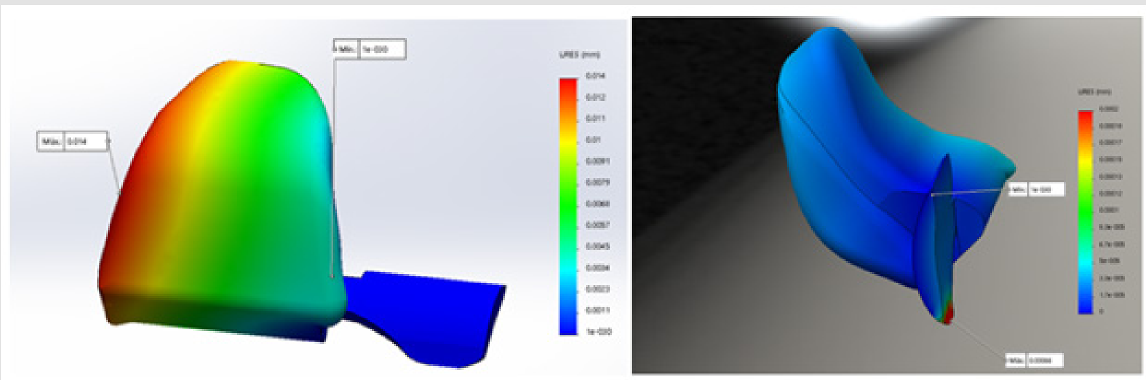

Figure 5: Results of the displacement of the cantilever bridge cemented with Relyx U200 after the application of forces.

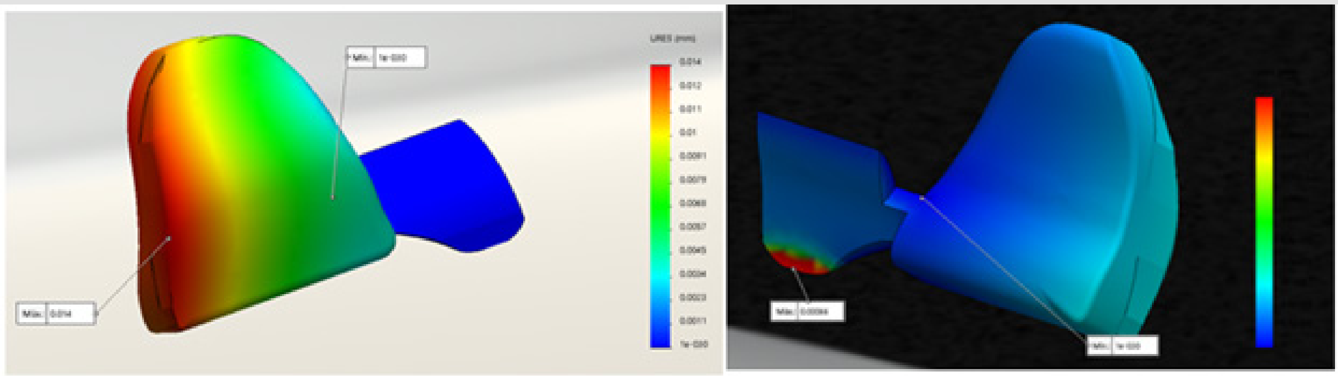

Figure 6: Results of the displacement of the cantilever bridge cemented with Relyx ARC after the application of forces.

The main advantage of the use of adhesive fixed prostheses is the possibility of making conservative wear on the enamel surface [7]. Affuer M, et al. [27], indicated in their study that the average thickness of enamel at the canine level is 2.15mm; therefore, the preparations in this study covered only 1mm of enamel, on the palatal surface of the canine, sufficient space for the lithium disilicate retainer and cement. The present investigation does not agree with the finite element study of Dal Piva A, et al. [17], who made more conservative preparations of 0.5mm for lithium disilicate adhesive fixed prostheses. However, in this study the minimum thickness of the material was also considered, which is 0.8mm [28]. In this study, both self-adhesive and conventional dual resinous cement acted in the same way, and this agrees with that mentioned by Wei Y, et al. [25] who, in their systematic review on the failure rate and complications of different designs of adhesive fixed prosthesis in the anterior sector, mentioned that it is possible that the use of different resinous cements does not influence the risk of prosthesis failure in clinical practice. Likewise, in the study by Upadhyaya V, et al. [29] on the shear resistance of conventional, self-etching and self-adhesive resinous cements, they concluded that total-etching resinous cement is the most reliable and clinically recommended to achieve a long-lasting bond. duration between a lithium disilicate restoration and the tooth. On the other hand, the results of this study do not agree with the research of Penteado M, et al. [2], who evaluated cements with different modulus of elasticity using RBFDP of lithium disilicate and observed a variation in the compressive stress, unlike the present investigation where the results were the same. These data may be discrepant due to retainer design; since in the present study the thickness was greater; therefore, this factor should also be evaluated.

The forces applied in this study were 100N in a horizontal direction at the level of the palatal aspect of the canine and 100N in an oblique direction, at an angle of 45° to 2mm from the incisal edge of the pontic, as in other finite element studies that evaluated fixed adhesive prostheses in the anterior sector, such as those of Penteado M, et al. [2] and Dal Piva A, et al. [17]. In this investigation, a normal bite force was applied as in the study by Toman M, et al. [30] and a parafunctional force was not considered because Tezulas E, et al. [13] reported that this type of prosthesis is contraindicated in such cases. There is great controversy regarding the design of the adhesive fixed prosthesis, since it may have one or two palatal retainers; however, as reported in the literature, the survival rate is higher in cases of structures with a retainer [31,32]. In the same way, in the finite element study by Dal Piva, et al. [17] where they evaluated three different adhesive fixed prosthesis designs, two models with a palatal retainer (one at the level of the canine and the other at the level of the central incisor) and a model with two palatal retainers in the upper left sector, obtaining as a result that the highest stress values were found in structures with two retainers. The explanation of this event is based on the micro-movements of each tooth in the mouth; that is, it is due to the degree of physiological mobility that the abutment teeth present during their function when they come into contact with the opposing pieces [25]; therefore, in the case of a cantilever bridge, the pontic moves in the same direction with the tooth in which it has been retained, as it only has one pillar [12]. Likewise, Tezulas E, et al. [13] and Chen J, et al. [33] mentioned that the canine is the best abutment for a cantilever bridge in this sector, because this piece has a long root and would adequately support lateral forces during chewing. For this reason, in the present study all the data mentioned above were taken into consideration and a cantilever bridge cemented in the canine tooth was selected for evaluation.

Despite the benefits granted by virtual design studies, these present limitations, the main one being the impossibility of simulating a real situation in the mouth, since in this case factors such as humidity, temperature or pH are not valuated, which if they could influence a clinical scenario. Likewise, the polymerization contraction, the management of the adhesive material and the

DOI: 10.26717/BJSTR.2022.44.007075

presence of temporomandibular disorders are elements that also influence and may even modify the prognosis of these rehabilitation treatments in the future.

Finite element analysis is a useful tool for the evaluation of the mechanical behaviour of the fixed adhesive prosthesis. These are considered minimally invasive, aesthetic and economic treatments.34 Based on the findings of this study, it is indicated that the mechanical behaviour of different dual resinous cements, with a different clinical protocol, behave in the same way when receiving masticatory forces. However, it is suggested to follow this line of research considering that cements, being found in an oral environment, can be affected by various factors such as saliva, which were not considered in the present investigation as they are virtual simulation.

Conclusion

It is concluded that the use of dual resinous cement does not influence the resistance of the cantilever bridge with a palatal retainer, finding equality between the distribution of compressive stresses and displacement of the prosthesis when using Relyx U200 cement such as Relyx ARC through finite element analysis. In the same way, new thesis students are recommended to evaluate the dynamics of the cantilever bridge cemented in the palatal side of the canine, considering the lateral forces that these pieces receive, since the mechanical behaviour could vary; likewise, it is suggested to carry out an in vitro study using the results of the present study, where the behaviour of the different types of dual resinous cements could be evaluated; and also, carry out finite element studies based on the design used in this research, where the retainer has different thicknesses.

Conflict of Interest

The authors declare that they have no conflict of interest.

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ISSN: 2574-1241

DOI: 10.26717/BJSTR.2022.44.007075

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