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Comparative evaluation of frictional resistance of extracoronal attachments of different designs and lengths in fixed partial denture: A finite element analysis

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Abstract---Aim: The purpose of this study was to evaluate the effects of different extracoronal attachment lengths and designs on frictional resistance and the vertical force required to create that resistance in fixed partial dentures (FPD). Setting and Design: Finite element analysis. Materials and Methods: Four manufacturers were considered for the FPD's extracoronal attachments because to their varying designs and length options (3 mm, 3.5 mm, 4 mm, 4.5 mm, and 5 mm). Catia V5 software was used to create 3D models of the samples and perform simulations on them. To simulate medical facilities, the application was adjusted to take into consideration the characteristics. The amount of frictional resistance and the required

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vertical force for that resistance were calculated by finite element analysis using ANSYS workbench 15.0. Statistical Analysis Used: ANOVA and Tukey's *post hoc* test. Results: When compared to Panavia SA cements, the average microhardness of Variolink N resin cements was much higher (P 0.001). Compared to Panavia SA resin cements, the sorption/solubility of Variolink N cements was statistically substantially lower at the 0.05 level. While the sorption/solubility of the resin cements was unaffected by the ceramic hue ($P > 0.05$), the microhardness of both cements was dramatically impacted (P 0.001). Conclusion: Resin cement, and particularly Panavia SA, has a lower microhardness when monolithic zirconia is interposed between the two. With an increase in chroma saturation, ceramics' microhardness decreased in Variolink N. However, in Panavia SA, the hues made a difference. The sorption and solubility of both cements were similarly undifferentiated statistically. The microhardness of both cements decreased as the water content increased.

***Keywords*---**Attachments, fixed dental prosthesis, force, frictional resistance, length and design of attachment.

Introduction

Prefabricated attachments with retentive components located beyond the natural abutment tooth shape are known as extracoronal attachments. [1] It is often used in fixed partial denture cases with pier abutment teeth for the purpose of controlling stress distribution (FPDs). Attachments in FPD are selected based on many factors, including the periodontal health of the teeth serving as abutments, the desired attachment location, the length of the connection, and the material used to make the attachment.When a rigid FPD is supported by a pier abutment, the tensile pressures acting away from the fulcrum might induce the retention failure of the FPD's terminal retainer.The connection area and the cervical region of the prosthesis, next to the edentulous ridge, experience the greatest occlusal forces during function [2,3].

Long-term prognosis is heavily influenced by [2] the way in which stress concentration at connections is managed. Nonrigid connections were proposed as a means of lowering failure rates. Choosing the right connection for each individual therapeutic situation might be difficult. Information on frictional resistance and the force required to simulate normal tooth movement of various attachments is also very useful for clinical selection.

Frictional resistance slows down or stops the movement of one body relative to another for the reasons the name suggests. Estimating frictional resistance is essential for research and practical use of flexible, plastic, and adaptable (FPD) connections and attachments. Almost no studies have really attempted to determine these figures. However, it is difficult and prohibitive to directly measure the frictional force and stress distribution at these intraoral locations in a clinical situation. Using the finite element method (FEM) to determine the frictional resistance attachment in FPD is a tried-and-true technique.The study was based on the premise that the various extracoronal attachments used in FPD would all exert the same vertical force and frictional resistance. The study's goal was to evaluate the differences in frictional resistance and the amount of vertical force required to induce friction between different lengths of the Vario-Soft 3 conical bridge, Preci-Vertix standard, Preci-Vertix P, and the PH Conix-PH Intrax attachments.

Materials and Methods

There was approval for the flow study by the institutional ethics committee. There were a total of five different sizes and four different designs of semiprecision extracoronal connections for FPD (3 mm, 3.5 mm, 4 mm, 4.5 mm, and 5 mm). French company Dassault Systems' (CATIA V5) software was used to create scaled and detailed 3D models of connections. The materials used in the models were consistent in every way. Multiple examples of each of the four possible plan connections were shown, ranging in size from 3 mm to 5 mm. Limited component analysis was performed in ANSYS workbench 15.0. (Swanson Analysis Inc., Houston, PA, USA). Every model was dissected into its component parts. The assumption was made that every component was linked to others through a set of discrete nodes. In order to calculate the maximum von Mises stresses, the models were meshes. As a result, the model could only be positioned in a backwards orientation. The attachment's fixed matrix and moveable patrix were made to fit any clinical setting. To better represent the clinical setting, we integrated the material characteristics into the models. Friction between the attachment's matrix and patrix was kept constant. Calculating frictional resistance is made easier with the use of ANSYS software, which displays quantitative von Mises stress and a graphical representation of the stress distribution pattern using a variety of colors. The following formula was used to determine frictional resistance:

Results

Tables 1 and 2 provide descriptive information on the amount of force and frictional resistance for each design. The average values for the forces show that the Vario-Soft 3 conical bridge requires 10.02 N, the Preci-Vertex standard requires 7.16 N, and the Preci-Vertix P requires 12.7 N, and the PH Conix-PH Intrax requires 4.1 N. Preci-Vertix P averages were the highest of any attachment. The average frictional resistance for the Vario-Soft 3 conical bridge was 8.90 N, whereas it was 6.7N for the Preci-Vertex standard, 2.40 N for the Preci-Vertix P, 4.8 N for the PH Conix-PH Intrax. Results were statistically significant ($P < 0.05$)

Table 1: Descriptive statistics for force among the four groups

Group	*n*	Mean	SD
Vario-Soft 3 conical bridge	5	10.02	2.52
Preci-Vertix standard	5	7.16	1.27
Preci-Vertix P	5	12.70	4.07
PH Conix-PH Intrax	5	4.10	0.94
SD: Standard deviation			

Table 2: Descriptive statistics for frictional resistance among the four groups

Group	*n*	Mean	SD
Vario-Soft 3 conical bridge	5	8.90	1.95
Preci-Vertix standard	5	6.70	1.36
Preci-Vertix P	5	2.40	0.39
PH Conix-PH Intrax	5	4.80	0.95
SD: Standard deviation			

Discussion

Findings from this investigation provided evidence against the alternative theory. Different kinds of attachments and lengths produced widely varying levels of frictional resistance and vertical force. It is possible, within normal physiological conditions, for the FPD to move, as held in place by the teeth of the abutment. The prosthesis, the arch's curvature, and the position and kind of abutment teeth all have a role in how easily teeth may shift. [5] For long-span FPD in particular, the stresses caused by opposing movements are very difficult for the abutment teeth to endure, having a significant effect on periodontal health[6]. To illustrate, here is Figure 9. An extrusive force is generated at the terminal abutments due to the tensile tensions exerted by the retainer and the abutment. Increased susceptibility to cavities and retention issues might result from a marginal seal that has been broken. [7] It has been suggested in the literature that a nonrigid connection be used to reduce the destructive forces conveyed to the abutment teeth, as detailed by Lin et al. [8]

Different attachment systems have unique biomechanics. Because of the adaptable attachment designs, the abutment teeth's stress distribution may be changed. [9] This study demonstrates that the strength of the attachment increases in direct correlation with its angular motion. The generated force should be a close match to the tooth's physiological movement to prevent the terminal abutments from becoming unbonded. “It has been shown that the frictional resistance and vertical force are both directly related to the length of the attachment teeth or abutment teeth. More force and frictional resistance cause more wear on the attachment, reducing its efficacy. Greater forces increase the probability of clinical failure of the abutment and prosthesis. [10] An attachment with excellent frictional resistance that corresponds to the natural tooth movement is optimal for transmitting forces to the abutment teeth.[11]The direction of an attachment motion might be either horizontal or vertical. [12,13] The periodontal ligament places physiological limits on what kinds of motion are possible. Vertical motion is given more weight in the attachment selection process than horizontal motion because of the higher frictional resistance encountered while moving upwards. [14,15,16]

The finite element method (FEM) has been shown to be a valuable tool for studying intricate in vitro and in vivo experiments. It is more precise and takes into account factors like the model's shape, node count, element count, and input attributes. [17,18] As an in vitro research method, FEM has constraints that prevent it from being directly transferred to the clinic. The study's design and implementation are technically challenging and need specialist knowledge. [19,20]

Catia V5 was used for the development of the 3D models. With the help of ANSYS workbench 15.0, we calculated the frictional resistance and the force. In comparison to competing software, ANSYS Fluent significantly shortens the required convergence time.

To keep abutment teeth in good condition, it is important that attachments move in the same way as teeth do. It is crucial to choose the right design and attachment length for a certain tooth location in the arch. "According to the results, the Vario-Soft 3 conical bridge had the lowest coefficient of friction compared to the Preci-Vertix standard, the PH Conix-PH Intrax, and the Preci-Vertix P. Comparing Preci-Vertix P to the Vario-Soft 3 conical bridge, Preci-Vertix standard, and PH Conix-PH Intrax, Preci-Vertix P had the strongest vertical force." In clinical settings, a higher friction resistance attachment should be employed when more movement than is considered physiologically normal is anticipated. [1] As can be observed in Figure 9, the front teeth are more mobile than the posterior teeth and so need a higher frictional resistance attachment. Between 3 and 5 mm is the sweet spot for attachment length in most circumstances. In addition to minimizing gum irritation, these lengths ensure a gap of at least 2 mm between the gingival floor of attachment and the marginal gingiva. [21]This research may be utilized to inform clinical decision-making when selecting an attachment, taking into account variables including abutment tooth length, frictional resistance, and predicted pressures. The Vario-Soft 3 conical bridge is the ideal choice for back teeth with an abutment length more than 5 mm, while the Preci-Vertix P is the greatest choice for front teeth. Increased friction attachment is suggested for abutments with a length less than 5 mm. The Vario-Soft 3 conical bridge for front and back teeth is an effective means of regulating the motion and force generated inside abutments. Significant limitations associated with in vitro study design are included in this research. Long-term follow-up studies in the future are crucial for greater clinical adoption.

Conclusion

As the length of a connection increases, so does the force and frictional resistance it encounters. The Vario-Soft 3 conical bridge has the greatest frictional resistance while the Preci-Vertix P has the maximum force.

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