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Effect of Direct Relining on Stresses at the Denture Base and the Metal Frame of Removable Partial Dentures

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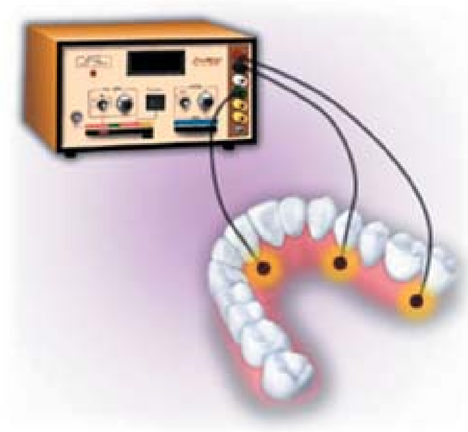

Abstract

The Kennedy Class I removable partial denture (RPD) can cause stress to supporting hard and soft tissues and may lead to harmful effects. The purpose of this study is to investigate the pattern of these stresses in three different positions before and following a relining procedure. Ten patients, five males and five females, with a lower distal extension RPD and an opposing upper class III type RPD were selected for this study. Strain gauges together with a strain gauge indicator were used to study the pattern of stresses in three selected positions. Some changes were significantly different at the site of the denture base and at the metal frame near the direct retainer. After relining, the stresses were shared partially by the abutments and partially by the tissues. Maximum stresses were reported during swallowing. No significant difference was noticed between males and females.

Keywords: Partial denture, relining partial dentures, tissue stress

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Introduction

Stresses to abutment teeth created by a removable partial denture (RPD) and the underlying tissues are well documented by other authors.[1-7] To overcome this problem and to minimize the stresses transmitted to the abutments and soft tissues, some authors concentrated on impression techniques.[8-15] They concluded the basic problem of RPD stabilization is to equalize the resilient and the non-resilient support. Achieving and maintaining stability of a denture base are the most important factors in the long-term success of a mandibular distal extension RPD and its retained supporting structures.[15] They described the altered cast impression techniques. Others also concluded the altered cast impression technique provides the least movement of extension bases under occlusal load compared to the bases processed on an anatomic cast.[16-18] The fit of a RPD can also be achieved by direct or indirect relining of the base of the RPD.[19-22] This can be accomplished directly in the oral cavity using auto-polymerizing resin[23, 24] or indirectly through the use of self-cure acrylic resin.[23-25] Several authors have concentrated on reducing the forces by proper design of the RPD.[26-31]

The purpose of this study is to investigate the effect of a direct reline on the stresses transmitted to direct and indirect retainers via the minor connectors as well as the distal extension base.

Materials and Methods

Patient Selection

Ten healthy partially edentulous patients (five females and five males) were selected for this study. The age group ranged between 30-55 years old with a mean age of 43 for males and 37 for females. All patients needed a lower bilateral distal extension RPD (Kennedy Class I) and an upper RPD (Class III). The subjects were informed about the steps required in the fabrication of a RPD as well as the experimental procedures in the study.

Construction of the RPD

Preliminary impressions were made using an irreversible hydrocolloid alginate impression (Jeltrate Dentsply, USA). The water powder ratio was measured according to the manufacturer's instructions. The water temperature was controlled, and the mixing time was standardized for all patients. Diagnostic casts were constructed from artificial stone (Modern Material, USA), were surveyed, and acrylic custom trays were fabricated. Mouth preparations on natural teeth were carried out for each case in accordance with the required design as dictated by the diagnostic casts. The preparations were performed in the same sequence for all lower cases. Custom trays were border molded using a green stick compound (Kerr, Italy), and final impressions were taken using Permalastic™ regular impression material (Kerr, USA). Impressions were boxed and poured using die stone (Velmix™, Kerr, USA) to form the master cast.

All RPD frameworks were constructed by the same dental technician at the Dental College at King Saud University. The chrome cobalt (Wironit™, BEGO, West Germany) framework was then inspected in the patient's mouth for adaptation and high spots were adjusted. A face bow (Hanau™, NY, USA) was used to secure the upper cast to model H-2 Hanau™ articulator (Teledyne, NY, USA). Maxillo-mandibular relations were established using occlusal rims on acrylic record bases.

The lower casts were mounted to the upper casts in centric relation and artificial teeth were selected using the appropriate criteria for each patient. The same cuspal incline (30°) acrylic teeth were used for all cases and occlusion was balanced.

The trial denture was tested in the mouth and then the RPDs were finished and polished. Three follow-up appointments (24 hours, 1 week, and 2 weeks, respectively) were given to the patients to evaluate their RPDs. The occlusion was adjusted using articulating paper as a guide. All sore spots were identified using PIP™ (Mizzy, USA) pressure indicating paste. The evaluation was carried out for all patients until all patients were comfortable with their RPDs. The patients were then recalled after three months for the experimental procedures.

Installation of Strain Gauges

Three positions were selected to solder the strain gauges as follows:

- The first at the lingual side of the acrylic base
- The second at the area of minor connector to the direct retainers
- The third one at the area of minor connectors to the indirect retainers

The soldering procedure did not affect the quality of the strain gauges, since they responded well during the experimental procedures (Figure 1).

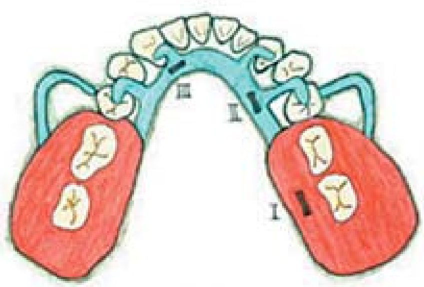


Figure 1. The three positions of the strain guages.

Figure 2. Strain guage type 3800.

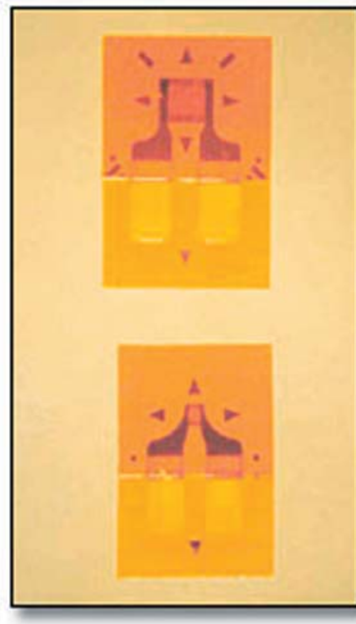


Figure 3. The strain guages used.

Figure 4. The UV recorder.

Data Collection Tools

The following data collection tools were used in the study.

- A 3800 wide range strain indicator (Figure 2)
- Strain gauge (linear type CEA-06-015-120 gauge factor –2.08) (Figure 3)
- X-Y chart recorder (Princes 80-No. 2133), which is used for the translation of the strain of RPD in the graphs (Figure 4)

Calibration of the System

The aim of calibration is to determine the relationship between the load applied and the strain signals received from the strain indicator. The calibration of the masticatory forces applied on class I (RPD) was done as follows:
Figure 5. The calibration system.

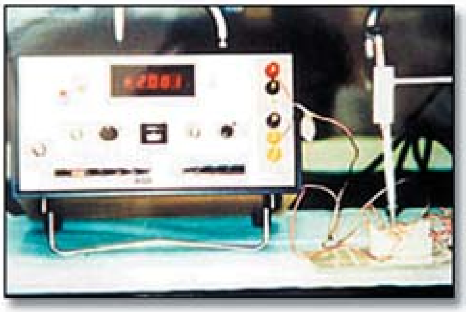


Figure 5. The calibration system.

Figure 6. The patient during the experimental procedure.

The experimental RPD was constructed on a model (Figure 5) and then the strain gauges were applied on the positions described previously. From each position, the wire of the strain gauge was connected to the strain gauge indicator and to the x-y chart recorder through the strain indicator type 3800. Known loads were applied. The loadings started by adding 1 kg, 2 kg, 3 kg, then 4 kg at a time. It was found the strain resulted was proportionally related to the load in a linear relationship. It was also found each kilogram is represented by 2 mm as was indicated from the chart paper.

These procedures were repeated three times for each position, and the mean values were compared for the linearity of the system. Calibrations were done for each patient before the experiments were conducted *in vivo*.

Experimental Procedures

After the connection of the RPD to the model 3800 strain indicator, the denture was inserted into the patient's mouth. Peanuts were found to be a suitable material for the test. Five grams were given to the patient to chew, and the chewing time (from start to finish) was recorded in the x-y chart recorder via the strain indicator (Figure 6).

Experimental procedures were repeated three times for each position and for each patient. A space of 2 mm was made to accommodate the relining material. The lower RPD was then relined with a self cure acrylic (*Kerr/Dentsply, USA) resin, which was mixed according to the manufacturer's instructions. Vaseline was applied on the oral tissue as a separating medium to protect the patient from any irritation, which may result from the free monomer or the exothermic reaction. The denture was left in position for five minutes, the RPD was then finished, polished, and the occlusion was checked. The signals were recorded in the x-y chart recorder before, as mentioned above, and after reline procedures in the three positions and the stress was evaluated using the formula.

Results

The forces in kilograms for all the cases before and after reline are shown in Table I. These readings were based on the calibration procedure that each kilogram (kg) is presented by 2 mm in the recorded chart. The means and standard deviation in the three positions were compared statistically using Paired t-test. (Table 2)

The findings indicated there was a significant difference before and after the reline procedure in positions I and II, respectively (Table 3). The stresses applied before and after reline are shown in Table 3. The calculations were done by using the formula: stress is equal to f/a where (f) is the force applied and (a) is the strain gauge area. The one-way Anova was conducted (Table 4). It was found there is a statistically significant difference for the average of the three positions.

Discussion

This is one of a few studies done *in vivo* to investigate the effect of a direct reline on distal extension RPDs using strain gauges and a strain indicator type 3800.

Strain gauges had been used for about 30 years in clinical research on the surface of dentures to study their deformation. Due to their small sizes, these gauges were almost ideal for measuring deformation under clinical conditions as they

Table 1. Forces in kilograms (cross section area of strain guage) in three positions and for all cases.

Subjects	Before Reline			After Reline		
	Position I	Position II	Position III	Position I	Position II	Position III
	Max.-Med. -Min.	Max.-Med. -Min.	Max.-Med. -Min.	Max.-Med. -Min.	Max.-Med. -Min.	Max.-Med. -Min.
1	3-1-0.5	2-1-0.5	1.5-1-0.5	4-2-1	2.5-1-0.5	-1-1-1
2	4.5-1.5-0.5	4-1-0.5	2-2-1	5-2-1	3.5-1-1	2-1-0.5
3	3.5-1-0.5	2-1.5-0.5	2-1-0.5	4-2-1	2-2-0.5	2-1-0.5
4	5-2-0.5	4.5-1.5-0.5	3-2-1	6-4-2	4.5-2-1	2-1-0.5
5	5.5-4-1	5-3-0.5	5-1-0.5	7.5-4-2	6-2-1	2-1-0.5
6	3-2-1	2-2-1	2-1-1	4-3-1	3-2-0.5	2-1-0.5
7	5-4-1	4-3-2	3-2-2	5-4-2	3-2-1	2-2-0.5
8	3.5-1-0.5	3-1-0.5	2-1-0.5	4-2-1	2.5-1-0.5	1.5-1-0.5
9	4-2-1	4-1.5-1	3-2-1	4-3-2	3-1-0.5	2-1-0.5
10	5-2-1	4-2.5-1	3-2-1	5-3-2	3-2-1.5	2-2-1

Max = Maximum
Med = Medium
Min = Minimum

Table 2. Different forces applied in three positions during chewing peanuts with Pair t-test.

	Before Mean SD	After Mean SD	Pair t-test
First Position			
Maximum	4.2 ± 0.919	4.85 ± 1.156	0.0095
Median	4.2 ± 0.919	2.9 ± 0.876	0.00123
Minimum	0.75 ± 0.264	1.5 ± 0.527	0.000423
Average	2.33 ± 0.685	3.083 ± 0.767	0.000037
Second Position			
Maximum	3.45 ± 1.117	3.3 ± 1.159	0.559
Median	1.55 ± 0.896	1.6 ± 0.516	0.823
Minimum	1.05 ± 0.685	0.800 ± 0.349	0.178
Average	2.0167 ± 0.626	1.900 ± 0.539	0.414
Third Position			
Maximum	2.65 ± 1.0014	1.7500 ± 0.425	0.0082
Median	1.4 ± 0.516	1.300 ± 0.484	0.591
Minimum	1.00 ± 0.577	0.600 ± 0.218	0.053
Average	1.683 ± 0.481	1.217 ± 0.209	0.0091

Table 3. Stress is in the cross section area of strain guage before and after reline.

	Before		After	
	Force Kg	Stress Lb/inch^2	Force Kg	Stress Lb/inch^2
First Position	2.33	17117.73	3.08	22649.77
Second Position	2.017	14818.22	1.9	13958.67
Third Position	1.68	12364.44	1.22	8940.89

Table 4. One-way ANOVA for three positions of the average value.

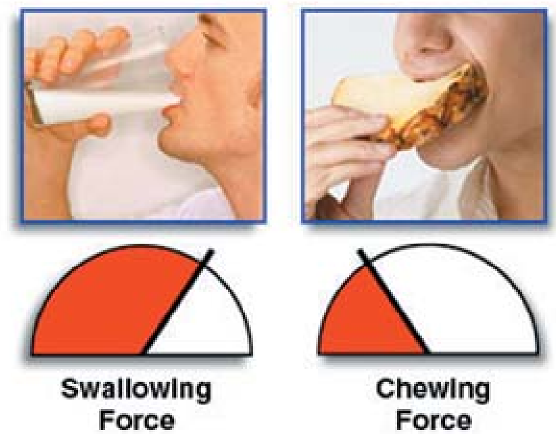
SV	SD	SS	MS	F	P
Between	2	7.846	3.923	27.20	0.0001
Within	27	3.894	0.1442		
Total	29	11.741			

Where:
SV = Source of variation
SD = degree of freedom
SS = Sum of square
MS = Mean square
Significant level at 0.05

record the minimal interference during function.[31, 32] However, there are certain limitations for the use of strain gauges. First, the gauges have to be effectively sealed from the oral cavity to prevent electric short circuits which occur when strain gauges are exposed to saliva. Second, in order to measure strain correctly gauges have to be firmly adhered to the surface of the appliance under examination, and they must also possess properties compatible with the particular type of material used for the manufacture of that appliance. Third, strain gauges can only measure surface strain at one point.[33]

Strain gauges are also very highly sensitive to temperature. The calibration in this study was done in vitro due to the fact there is difficulty in performing it intra-orally, however, it was recorded in the literature by MacColl et al.[34, 35] They found calibration at 22°C and 37°C did not show any variation in the amplitude, while Kurt et al.[35] found the intra oral and extra oral calibration showed differences less than 2%.

The forces before relining and after relining were shown to be highly significant in all positions except in the second position (Table 4). These findings are due to the fact direct reline gives more adaptation of the base and are similar to those reported by Maxfield et al.[38] This results in more tissue support with less denture displacement. Movement of the denture base is decreased and less force is transmitted to the abutment. On the other hand, it was found the force exerted during swallowing is greater than the force exerted during mastication. These results are in agreement with Kydd et al.[36]



The increase in force during swallowing is mainly due to the fact the jaw remained closed for a longer period of time than during occlusal contact when chewing. Gibbs et al.[39] found the phase of occlusal contact during swallowing was considerably longer than the phase of occlusal contact during chewing. Ogata[40] had the same conclusions, i.e., the force exerted during slow chewing was more than the force exerted during rapid chewing. This study also showed insignificant differences in the magnitude of force during mastication between males and females. These results support the findings of other studies.[33, 36, 37] They concluded there was no correlation in the biting force due to the difference in chewing habits, motivation, anxiety, psychological factors, and muscle action.

The mean force applied on RPDs in this study at the edentulous base is between 2.3–3.07 kg; other studies by Ogata et al. (1983) found the mean force is between 1-2 kg and Yurkstas and Curby[37] (1953) measured the average force of mastication 0.3-1.8 kg. Whereas, Maxfield et al.38 (1979) concluded the average force during normal mastication for RPD is 2 kg.

Conclusions

From the limitations of this study, the following conclusions can be drawn:

1. The strain gauge and 3800 strain indicator showed an accuracy and linearity in all cases.
2. The relining procedure has an effect on forces transmitted to direct as well as indirect retainers via major and minor connectors.
3. These results prove the importance of direct relining as a simple procedure when compared with the altered cast impression and should be a mandatory procedure for all distal extension mandibular RPD.
4. Maximum forces were found to be near the abutment teeth and minimum to the indirect abutments, i.e., away from the biting force.
5. Maximum occlusal force was found during the swallowing phase.
6. There was no significant difference in forces exerted on RPD between males and females.

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