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CLINICAL EVALUATION OF CHEWING EFFICIENCY FOR FLEXIBLE REMOVABLE PARTIAL DENTURES IN BILATERAL FREE-END SADDLE CASES

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ABSTRACT

Statement of problem: Increasing flexibility of removable partial denture increase the patient comfort and esthetics at the cost of bite force and chewing efficiency. **Purpose:** To compare and study the variation of chewing efficiency in different types of thermoplastic denture base materials used for restoring Kennedy class I removable partial dentures. **Materials and Methods:** Eight patients were included in the study. Four types (groups) of removable partial dentures will be made for every patient in the test group: thermoplastic Nylon RPD, thermoplastic Acetal RPD, thermoplastic PMMA RPD and thermoplastic PMMA with hard PMMA combination. Nylon and Acetal dentures were made using thermo-injectable technique. F. PMMA and H. & F. PMMA dentures were made using compression moulding technique. Chewing efficiency was measured after 1 week, 3 months and 6 months follow-up period for the two types. Chewing efficiency was evaluated by colored chewing gum and computerized color analysis. The test data were collected and analyzed. **Results:** H. & F. PMMA and F. PMMA had higher chewing efficiency than Nylon and Acetal 1 week after insertion for all chewing cycles. Only 10 chewing cycles affected by increasing the follow up period and denture adaptation for all types. **Conclusion:** Combination of flexible denture base materials with hard denture base material is recommended to enhance chewing efficiency.

INTRODUCTION

Rehabilitation of missing dentitions with removable partial dentures (RPDs) is often utilized to improve patients' masticatory function. However, even if all missing teeth have been replaced, the masticatory function is usually improved to a lesser extent than that of the previous complete dentition. However, within our knowledge, this faith has been rarely confirmed by an intra-individual study. The transition of patients' masticatory function when switching from a complete dentate to RPD replaced condition remains unclear [(1)].

In the past, most studies employed masticatory performance and/or bite force as the objective measurements in evaluating masticatory function. Denture patients were reported as handicapped and have less masticatory performance and bite force, than people with natural dentitions. In inter-individual comparisons, masticatory performance and bite force of denture patients were about one-half to one-sixth those of dentate subjects, depending mainly on type of dentures and numbers and distribution of remaining teeth [(2,3)].

Effectively, during mastication, natural or artificial teeth are not simple tools that mechanically reduce the food to particles and mix saliva and the food to produce a bolus, easy to swallow. They also are essential to the neuromotor control of chewing and swallowing, through the sensory receptors [(4)]. Any oral disease that affects the numbers, the structure or the position of the teeth is supposed to have an impact on chewing and, in turn, on nutrition. A

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physiological approach is thus necessary to measure to what limits the edentulous status and their oral rehabilitation could affect the chewing function [5].

Mastication is a complex task that mixes voluntary and automatic motor pathways controlled by central nervous system pattern generators, and is regulated by the feedback from several receptors (extern-proprio and viscero-receptors). One of the factors leading to the decrease in chewing performance is the reduced bite force that denture wearers can develop owing to a lack of retention and stability of the denture [6]. Flexible dentures are an excellent alternative to traditional hard-fitted dentures. Traditionally dentures with a soft base increases comfort and provide more esthetics at the cost of chewing efficiency [7].

MATERIALS AND METHODS

Eight patients with bilateral free end saddle cases were the subject of the study. Patients will be selected from the outpatient clinic of Removable Prosthodontics Department, Faculty of Dental Medicine, Boys, Cairo, Al-Azhar University.

Four types of flexible removable partial dentures were made for every patient; thermoplastic nylon, thermoplastic acetal, thermoplastic PMMA and thermoplastic PMMA with hard PMMA combination. Each patient used each denture alternatively for 6 months. The time lapse for all dentures wearing was 2 years.

Clinical and laboratory procedures for all dentures were: Primary impression was made with irreversible hydrocolloid impression material. Custom tray was made with 2mm wax spacer. Elastomeric impression material with light body and putty was made. Duplication of master cast was done with the die stone. Jaw relation was made.

Nylon and Acetal partial dentures were made according to Injection molding technique [8]. Thermoplastic PMMA and combined thermoplastic & hard PMMA partial dentures were made according to Compression Molding Technique [9].

All groups were evaluated firstly for (one week, three and six months) follow-up periods. Two weeks a period of rest between groups. According to Schimmel et al. [10]. a two-color chewing gum* test for masticatory efficiency was used to evaluate the masticatory efficiency as follows: Samples of a two-color chewing gum were prepared from Gums in the flavors 'mint' (white color) and 'Watermelon' (Red color). Strips of 30 mm length were cut from both colors' and manually stuck together, so that the test strip presented were 30 x18 x 3 mm [11].

Patients were instructed to chew five samples of chewing gum for 10, 30 and 50 chewing cycles respectively. This test measures the ratio of pixels corresponding to unmixed color sections of the chewing gum to the number of pixels in the entire image. All samples were assessed after flattening to 1 mm thick 'wafers'. The unmixed pixels counted using Adobe Photoshop Elements to calculate the ratio of unmixed color to the total surface.

After chewing the gums, the samples were then spat into transparent plastic bags, which were labeled with corresponding numbers of strokes. Between the different tests an interval of at least 1 min was imposed to reduce the effect of fatigue. The total duration of the experiments was approximately 8 minutes.

A PC (Intel Pentium_ 3, 2 GHz, 256 MB) with Windows 7** and a Digital scanner*** were used. The wafers were scanned from both sides with a resolution 600 dots per inch. The scanned image was copied into an image of fixed size (1175 x 925) pixels and stored in Adobe Photoshop format (****. psd). Then the color range tool was used (fuzziness 20, 25, 30) to select the unmixed white parts of the image. The numbers of selected pixels were recorded from the histogram for each side and each tolerance and mean of those figures calculated (Fig.

1). Subsequently a ratio was computed for the Unmixed Fraction (UF) using the following formula:

$$\frac{(\text{Pixels white side a} + \text{Pixels white side b}) - 2 \times \text{Pixels of scale}}{2 \times \text{Pixels all}}$$

The result of this study will be statistically analyzed by Statistical Package for Social Sciences (SPSS) statistical software.

RESULTS

Chewing efficiency comparison according to denture type:

a) 10 cycles: (Table 1) (Fig. 2)

- **1 Week** after insertion: The patient recorded significantly higher Chewing efficiency (P<0.001**) for H. & F. PMMA in comparison to all other types. Also, Significant high chewing efficiency recorded for F. PMMA more than Acetal and significant high chewing efficiency recorded for Nylon more than Acetal.
- **3 Month** after insertion: The patient recorded significantly higher Chewing efficiency (P<0.001**) for H. & F. PMMA more than Nylon and Acetal. Also, Significant high chewing efficiency recorded for F. PMMA more than Acetal and significant high chewing efficiency recorded for Nylon more than Acetal. Thermoplastic Acetal recorded a higher significant difference as the lowest chewing efficiency compared with all other types.
- **6 Month** after insertion: The patient recorded significantly higher Chewing efficiency (P<0.001**) for H. & F. PMMA more than Nylon and Acetal. Also, Significant high chewing efficiency recorded for F. PMMA more than Nylon and Acetal. Significant high chewing efficiency recorded for Nylon more than Acetal and less than H. & F. PMMA and F. PMMA. Thermoplastic Acetal recorded a higher significant difference as the lowest chewing efficiency compared with all other types.

b) 30 cycles: (Table 2)

- **1 Week** after insertion: No significant difference (P=0.204) founded between different denture types during this period.
- **3 Month** after insertion: No significant difference (P=0.522) founded between different denture types during this period.
- **6 Month** after insertion: The patient recorded significant difference in chewing efficiency (P=0.034*) for Nylon less than H. & F. PMMA and F. PMMA.

c) 50 cycles: (Table 3)

- **1 Week** after insertion: No significant difference (P=0.995) founded between different denture types during this period.
- **3 Month** after insertion: No significant difference (P=0.136) founded between different denture types during this period.
- **6 Month** after insertion: The patient recorded high significant difference in chewing efficiency (P=0.001**) for Nylon less than all other denture types.

According to follow up periods for all denture types Nylon, Acetal, F. PMMA and H. & F. PMMA:

- **10 Cycles:** The patient recorded significantly higher Chewing efficiency score (P<0.001**) for P1, P2 and P3 records.
- **30 Cycles:** The patient recorded significantly higher Chewing efficiency score with Nylon denture type (P3=0.009**) for only P3 records. Also recorded significantly higher Chewing efficiency score with Acetal denture type for P2 and P3 only (P2<0.001**) (P3=0.034*). Finally, the patient recorded significantly higher Chewing efficiency score (P<0.001**) for P1,

TABLE (1) Chewing efficiency comparison according to denture type (10 cycles):

Chewing efficiency	Time of measurement	Denture type				Kruskal-Wallis test
		Nylon n=8	**Acetal n=8**	**Flexible PMMA n=8**	**Flexible and Hard PMMA n=8**	
10 cycles	**1w**	20026.0 [ab] (1690.0-40418.0)	27122.0 [acd] (1699.0-69884.0)	16736.0 [ce] (1501.0-40460.0)	14198.0 [bde] (867.0-24077.0)	P<0.001**
	3m	7696.5 [ab] (1268.0-20851.0)	12906.0 [acd] (2062.0-31641.0)	5699.5[c] (1505.0-19851.0)	4988.5 [bd] (690.0-13673.0)	P<0.001**
	6m	2754.5 [abc] (1004.0-5595.0)	3437.5 [ade] (1010.0-16967.0)	2315.0 [bd] (1423.0-4176.0)	1907.0 [ce] (263.0-3806.0)	P<0.001**

TABLE (2) Chewing efficiency comparison according to denture type (30 cycles):

Chewing efficiency	Time of measurement	Denture type				Kruskal-Wallis test
		Nylon n=8	Acetal n=8	Flexible PMMA n=8	Flexible and Hard PMMA n=8	
30 cycles	**1w**	103.0 (7.0-360.0)	140.5 (51.0-353.0)	114.0 (7.0-253.0)	119.5 (11.0-267.0)	P=0.204
	3m	109.5 (7.0-326.0)	111.0 (12.0-320.0)	98.5 (8.0-203.0)	80.5 (9.0-192.0)	P=0.522
	6m	87.0 [ab] (11.0-205.0)	71.5 (7.0-298.0)	69.0 [a] (7.0-191.0)	56.5 [b] (6.0-177.0)	P=0.034*

TABLE (3) Chewing efficiency comparison according to denture type (50 cycles):

Chewing efficiency	Time of measurement	Denture type				Kruskal-Wallis test
		Nylon n=8	Acetal n=8	Flexible PMMA n=8	Flexible and Hard PMMA n=8	
50 cycles	**1w**	22.0 (1.0-132.0)	27.5 (4.0-69.0)	24.5 (4.0-71.0)	31.0 (1.0-63.0)	P=0.995
	3m	34.0 (2.0-145.0)	19.5 (1.0-86.0)	15.0 (2.0-59.0)	15.5a (2.0-46.0)	P=0.136
	6m	18.5[abc] (4.0-73.0)	9.5 [a] (2.0-45.0)	14.0[b] (2.0-34.0)	8.5[c] (1.0-23.0)	P=0.001**

P2 and P3 records with F. PMMA and H. & F. PMMA type.

- **50 Cycles:** The patient recorded significantly higher Chewing efficiency score (P<0.001**) for P1, P2 and P3 records with all denture types.
- This demonstrated the rapid increase in chewing efficiency values in relation to the time elapse after insertion. Increase the time of adaptation Increase the chewing efficiency significantly. Except with Acetal for P1 records there was no significant difference recorded.

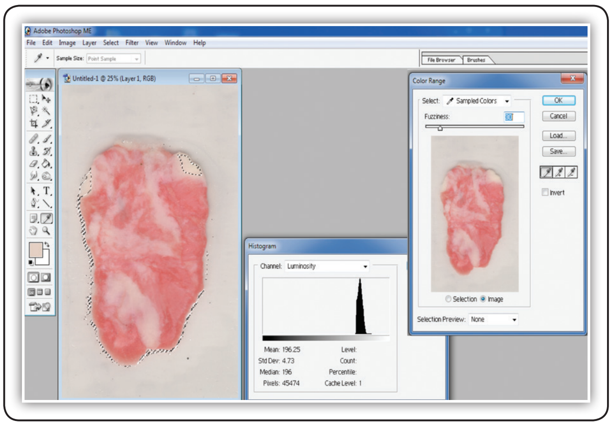

Fig. (1) Photoshop software used to identify the non-mixed white pixels by using color range tool (Fuzziness 20, 25, 30) and histogram tool.

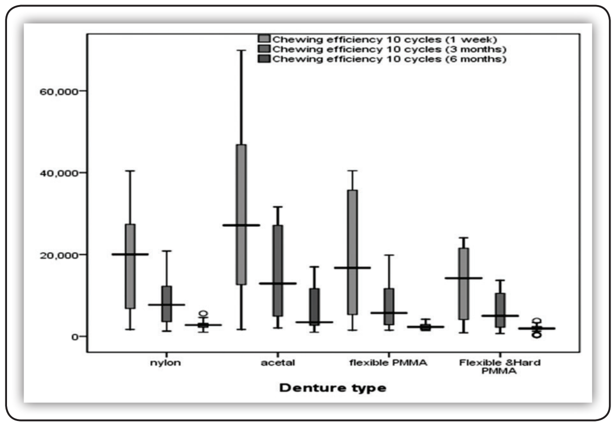

Fig. (2) Box and Whisker plot showing median of chewing efficiency measurement for (10 cycles) according to denture type and follow up periods.

DISCUSSION

Discussion of Materials and Methods:

Patients were selected with their age ranging from 40 to 50 (mean age of 45 years) to avoid muscle atrophy due to senility. There is variation in muscle efficiency due to age, as the patients in the same age group show almost the same muscle efficiency (12). The selected patients were female to avoid the difference in muscle efficiency between different sexes (13). Patients with systemic disease or neuromuscular disorders were excluded to avoid any effect on the muscle tone and hence resultant masticatory efficiency (14).

Patients with temporo-mandibular joint dysfunction were also excluded to avoid any disturbance in muscle behavior (15). Moreover; patients with abnormal ridge relationship were avoided because dentate subjects with normal occlusion were found to have a better masticatory efficiency than subjects with malocclusions. The abnormal tongue behavior or size and/or xerostomia or excessive salivation were exclusive factors during the patient's selection, as that may affect the dentures stability, retention and subsequent the patient's satisfaction rating (16).

The objective evaluation of masticatory efficiency was made for the current study, residual strips of the original gum were cut from pink and white colors in the dimensions of 30 mm x 18 mm x 3 mm and prepared according to the original protocol.[10] Two series of experiments were performed. First dentate participants sat upright and chewed all three gum types for 5, 10, 20, 30 and 50 chewing cycles, respectively. The chewing cycles were counted by the operator. Between each chewing sequence a pause of 1 min was respected, after the 50 chewing cycles the pause was 2 min. The specimens were then retrieved from the oral cavity, placed in a transparent plastic bag and subsequently flattened to a 1 mm thick wafer by pressing on a custom-made polyvinyl chloride plate with a milled depression of 1 mm 50 mm 50 mm. Additionally, in order to complete the range of color mixing, 10 unchewed gums of each specimen were analyzed (17).

Digital image processing of the two-color chewing gum test specimen provides reliable quantitative data for chewing efficiency. Visual assessments were less reliable but might still be useful in screening for chewing deficiencies in a clinical setting (17).

DISCUSSION OF RESULTS

Removable partial dentures are widely used in clinical practice and despite a decrease in the mean number of missing teeth observed in past decades, the demand for this type of dentures is still projected to grow due to an increase in human population and its longevity. However, despite the high prevalence of partial edentulism and widespread use of RPDs, the *in vivo* studies of chewing efficiency and occlusal forces in RPD wearers are extremely rare (18).

Chewing efficiency is determined by the number of missing teeth, number of opposing teeth pairs and, according to some authors, also by occlusal force (19,20). Paphangkorakit et al. (20) showed that chewing efficiency correlates with muscle work, but not with muscle effort and masticatory effectiveness (the ratio of masticatory performance, also referred to as chewing efficiency, to muscle work). Therefore, individuals who present with good conventional chewing efficiency are not necessarily effective chewers since they use more muscle work during the chewing.

However, our findings explained that the use of denture base materials with lower modulus of elasticity influenced the level of chewing efficiency dramatically for (10 chewing cycles). According to denture type we observed high significant increase in chewing efficiency for H. & F. PMMA & F. PMMA more than Nylon and Acetal in all follow up periods. We observed also no significant change in chewing efficiency for all denture type in (30 & 50 cycles) in all follow up periods except 6 months period Nylon demonstrated the least significant chewing efficiency compared to all other denture types.

Nevertheless, Wadachi et al. (21) showed that the dentures made of materials with modulus of elasticity lower than that of PMMA, such as Polyamide, can be deformed easily and as a result, a larger load is transmitted onto the mucosa under the denture. In view of these findings, it can be supposed that the use of materials with lower modulus of elasticity may result in pain due to greater mobility of the denture and its worse stabilization, both leading to a decrease in chewing efficiency. This can be changed due to the use of soft denture lining materials which evenly distribute the loads transferred onto the mucosa during chewing and thus relieve the soft tissues from mechanical stress, which, in turn, promotes an increase in both chewing efficiency and occlusal force (22,23).

Our observation that chewing efficiency did not change significantly with the time of denture wear for 30 and 50 chewing cycles is consistent with the results published by Aras et al [24] During a one-year follow-up, these authors did not demonstrate significant changes in the chewing efficiency of RPD wearers subjected to a chewing test with standard two-colored wax cubes. None of the previous studies analyzed the chewing efficiency in RPD wearers during a longer, several-year follow-up. We observed also a significant increase in chewing efficiency for 10 chewing cycles between follow up periods as the period of denture adaptation increased (1 week < 3 months < 6 months).

CONCLUSION

From this study we can concluded:

1- Increase flexibility of the denture base material (Low Modulus of Elasticity), Decrease the Chewing efficiency. Combination with Hard PMMA or Cast metal is recommended to enhance chewing efficiency.

2- Increasing denture adaptation period improved the chewing efficiency with fewer chewing cycles only.

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