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RESEARCH ARTICLE

ELECTROMAGNETIC RADIATION THERAPY EFFECT ON DIMENSIONAL STABILITY OF DENTURE BASES AND ITS ORAL HEALTH IMPACT ON DAILY PERFORMANCE

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Abstract

Background: The demonstration of moderately simple sterilization-disinfection measures in daily practice is very serious to decrease the probabilities of cross-infection as prosthetic appliances have to be sterilized prior to be transferred to the technician and patient. The used disinfection method should be properly selected due to its great effect on the physical and mechanical properties of denture bases.

Aim: This research was conducted to study the consequences of chemical and electromagnetic radiation disinfection methods on dimensional stability and oral health impact on daily performance. Also, to evaluate the effect of repeated microwave disinfection under different conditions.

Materials and Methods: Group I: Denture disinfection using (1%) sodium hypochlorite for 10 minutes. Group II: Denture disinfection using electromagnetic radiation (650 W for 3 minutes / once per week) and divided into 2 subgroups: Group II-A: Dentures kept dry during microwave disinfection. Group II-B: Dentures kept wet in distilled water during microwave disinfection. Group III: Denture disinfection using electromagnetic radiation (650 W for 3 minutes / twice per week) and divided into 2 subgroups: Group III-A: Dentures kept dry during microwave disinfection. Group III-B: Dentures kept wet in distilled water during microwave disinfection. Dimensional stability and patient satisfaction using (OIDP) questionnaire were evaluated after one- and three-weeks follow-up periods.

Results: Comparison between dimensional changes after 1st & 3rd week revealed insignificant difference in dimensional changes regarding Group I (expansion) & GII-A & GII-B (Shrinkage) after 3rd week as $P > 0.05$. On the other hand, there was a significant difference (shrinkage) in GIII-A & GIII-B after the 3rd week as $P < 0.05$. Oral health impact on daily performance (OIDP) revealed insignificantly decreased after 3rd week in all groups except GIII-B as OIDP significantly decreased.

Conclusion: Complete denture disinfection with sodium hypochlorite preparation showed the least dimensional change (Expansion) with higher patient satisfaction, while electromagnetic radiation treatment

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(microwave) of complete dentures showed higher dimensional change with lower patient satisfaction especially in wet conditions.

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Introduction:-

Dental prosthetic appliances are in continuous contact with normal oral contagious microorganisms such as viruses, bacteria, and fungi. While modifying or restoring these prostheses, clinicians and technicians might be at hazard of obtaining infections, moreover, cross-contamination to and from patients. Therefore, the presentation of moderately simple sterilization-disinfection measures in daily practice is very serious to decrease the probabilities of cross-infection as prosthetic appliances had to be sterilized prior to be transferred to the technician or the patient ^(1,2).

Moreover, removable prosthesis maintenance is very important among old ages as they reveal a decreased immune response to infections, and an increased physical impairment augmented by chronic diseases. Therefore, the establishment of an effective, applicable and inexpensive disinfection protocol is necessary to avoid oral problems associated with poor oral hygiene among denture wearers as it greatly affects esthetics and is almost always associated with foul odor ^(3,4).

There are several methods of removable prosthesis disinfection as mechanical methods, by using sonic and ultrasonic devices which are simple methods. However, some patients do not have the visual awareness or the physical skill to complete denture hygiene correctly, which leads to biofilm growth and the need for additional cleansing methods. Also, it may encourage possible denture abrasion. On the other hand, chemical methods are extra disinfection means that are very common, effective, and can be easily achieved by immersing dentures in alkaline glutaraldehyde, sodium hypochlorite, aqueous formaldehyde, or enzymatic preparations ^(5,6).

However, disinfection protocols using chemicals have many drawbacks as being timewasting, discoloration, and bleaching of the denture, having an expiration date, and eventual potential oral mucosa response. Also, several changes in physical & mechanical properties of denture base may be induced by using chemical disinfection protocols. Furthermore, chemical preparations might become captivated into the porosities and cannot be eradicated by regular soaking, thus, chemical preparations may be accidentally presented into the oral cavity ⁽⁷⁾.

Consequently, another protocol for prosthetic appliances disinfection is necessary. Recently, the electromagnetic radiation method which is based on electromagnetic heating has also been considered as one of the approaches of denture sterilization/disinfection, and as an alternative to chemical preparations due to no exceptional packing, has no expiration timing, and does not result in resistance to *Candida Albicans* ⁽⁸⁾.

The mechanism of microwave radiation disinfection is imprecise. Some research appealed its disinfection power to thermal nature directly, while others revealed that electromagnetic radiation directs the metabolic action of microorganisms in a way that might not be clarified by the thermal action only and clarified it to the interface of the electromagnetic field with the cells and the nearby liquid medium (non-thermal effects). However, a likely clarification of the non-thermal consequence of microwave radiation could be in the selectivity of absorption of electromagnetic radiation by exact serious biochemical molecules like nucleic acids and cell membranes which disturb the vital activity of microorganisms ^(9, 10).

Besides, because maximum microbial cells tolerate an electrical charge, usually negative, the possibility exists of the cell being mechanically disrupted by initiating it to oscillate quickly in the high-frequency field. Even with the trueness of the harms of microwave radiation, some investigators have credited the satisfactory consequences to water immersion during this procedure. This can be clarified based on the increased water temperature during electromagnetic radiation, which delivers equal thermal effects of the samples. Research concerning electromagnetic radiation disinfection of acrylic resins infected with *C. Albicans* revealed that all 5-minutes-irradiated acrylic resin specimens soaked in water were successfully sterilized, while the 3-minutes-irradiated specimens in a dry condition were only disinfected ⁽¹¹⁾.

However, when choosing a disinfection protocol, its consequence on the physical and mechanical characteristics of the denture materials should be considered properly, as the actual success of complete dentures stands on patient satisfaction with the dentures and their regular denture preservation. Therefore, the dentist should appreciate

satisfaction with dentures from the patient's viewpoint to improve communication with the patient and the success of the prosthetic appliance ⁽¹²⁾.

The electromagnetic radiation disinfection protocols for complete dentures are still debated because they might alter some material characteristics like color, hardness, roughness, dimensional stability, and flexural properties which may affect their clinical consequence. Few data are reachable on the consequence of repeated electromagnetic radiation disinfection on the dimensional changes of denture base materials in dry and wet situations ⁽¹³⁾. Therefore, this clinical study aimed to assess the effect of electromagnetic radiation disinfection with various frequencies on the dimensional stability of the complete denture and compare it with sodium hypochlorite disinfection as a control group.

Materials and Methods:-

Study design:

This study was carried out in the removable prosthodontics department, Faculty of Oral and Dental Medicine, Badr University in Cairo, and fixed and removable prosthodontics department at National Research Centre, Cairo, Egypt. The participants of this study were forty-five completely edentulous patients randomly distributed equally among 5 groups according to complete denture disinfection protocol as follows:

Group I: Denture disinfection using (1%) Sodium hypochlorite disinfection for 10 minutes.

Group II: Denture disinfection using electromagnetic radiation (microwave energy 650 W for 3 minutes / once per week) and divided into 2 subgroups:

Group II-A: Dentures kept dry during microwave disinfection.

Group II-B: Dentures kept wet in distilled water during microwave disinfection.

Group III: Denture disinfection using electromagnetic radiation (microwave energy 650 W for 3 minutes / twice per week) and divided into 2 subgroups:

Group III-A: Dentures kept dry during microwave disinfection.

Group III-B: Dentures kept wet in distilled water during microwave disinfection.

Sample Size Calculation:

The sample size was calculated depending on a previous study by *Jayaprakash Mugur Basavanna et al 2016* as reference ⁽¹⁴⁾. According to the prior data the difference in the response of matched pairs is normally distributed with a standard deviation of (0.02), the true difference in the mean response of matched pairs is (0.03), minimally the study needed 6 subjects in each group when the probability (power) was 0.8 and the type I error (α) was (0.05). The total sample size increased to 8 subjects per group to compensate for 20 % dropout.

Ethical Approval:

This study was carried out following the principles of the Declaration of Helsinki in 1975, and all patients were informed about the practical steps of this study and signed written approval consent.

The ethical approval was obtained from the Medical Research Ethical Committee (MREC) of the National Research Centre (NRC), with approval No. 18078.

Patients' Selection and Instructions:

A total of forty-five healthy patients, complete denture wearers, aged between 45-65 years old were included in the present study after proper intraoral & extraoral examination was performed. All included patients should be cooperative to follow all received verbal and oral hygiene instructions.

All the patients of the three groups were instructed to do the following: To remove the dentures after every meal to be rinsed under running water only, not to keep the dentures in any type of denture cleansers but keep it only in a cup of tap water & removal of the dentures overnight.

Complete Denture Construction and Disinfection:

All dentures were constructed following the conventional manner and randomly distributed according to disinfection method (N=8):

Group I- Sodium hypochlorite disinfection (immersion in 1% for 10 minutes) All dentures in this group were soaked in freshly prepared 1% of sodium hypochlorite for 10 minutes.

Group II- Microwave disinfection (650 W for 3 minutes / once per week)

1. **Group II-A:** All dentures in this group were disinfected in a microwave oven at 650 W for 3 minutes without soaking in distilled water, once per week.
2. **Group II-B:** All dentures in this group were kept in 200 ml of distilled water and then disinfected in a microwave oven at 650 W for 3 minutes, once per week.

Group 3- Microwave disinfection (650 W for 3 minutes / twice per week)

1. **Group III-A:** All dentures in this group were disinfected in a microwave oven at 650 W for 3 minutes without soaking in distilled water, twice per week.
2. **Group III-B:** All dentures in this group were kept in 200 ml of distilled water and then disinfected in a microwave oven at 650 W for 3 minutes, twice per week.

Evaluation of Dimensional Stability:

The linear dimensional stability of the dentures was evaluated by measuring the distance and area between reference points made on the buccal cusp of the first premolars (A&B) and the distobuccal cusps of the second molars (C&D). The distances between the points on the denture bases were then measured and recorded using a digital camera was placed on Tripod at a fixed distance of 30 cm from the dentures which placed on a black background to obtain a standardized snapshot position as shown in figure (1).

The camera zooming was also fixed during taking all dentures images. All dentures were photographed by digital camera and transferred to the computer. Dentures images were imported into a specific image analysis software program. A mean value of cross-palatal distances AB and CD defined the mean value for the mediolateral dimension, the mean distances AD and BC defined the mean value for the anteroposterior dimension. Area ABCDA was calculated as the sum area of the 2 triangles (ABD & BCD), measurements were recorded three times, and then the average was calculated. All the measurements were obtained at baseline, after 1 week, and after 3 weeks. Dimensional changes were calculated by using the mean difference. All data were recorded, tabulated, and subjected to statistical analysis (Digimizer image analysis, MedCalc Software, Belgium).

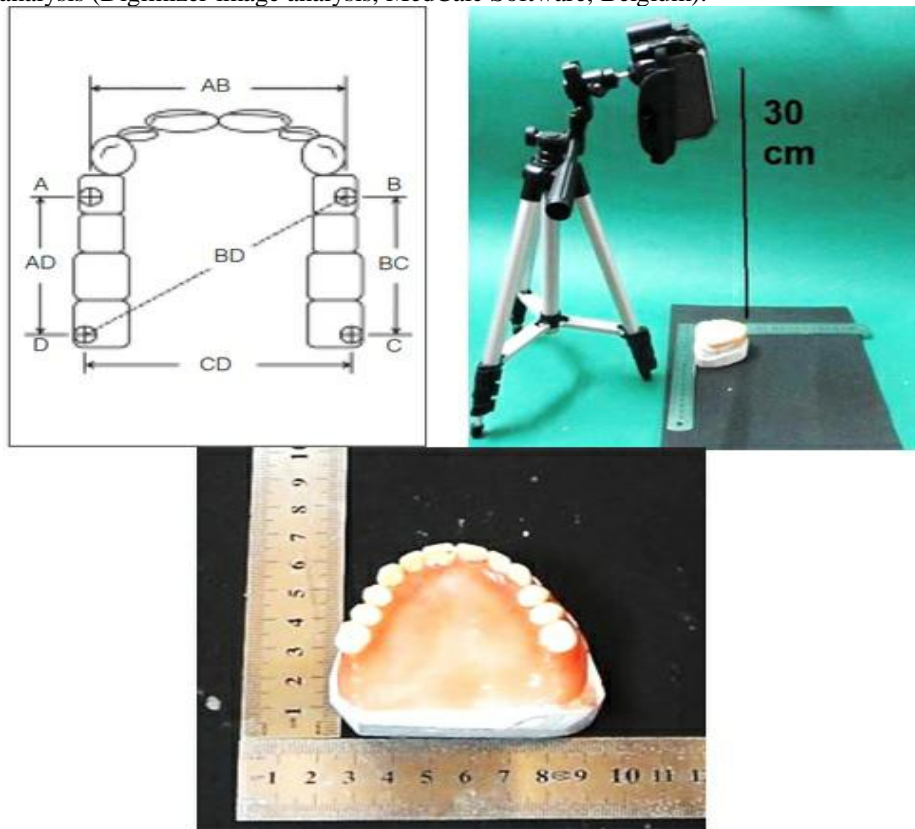


Figure (1):- A: Reference points for dimensional stability measurements in maxillary denture using computerized digital camera.

Evaluation of Oral Health Impact on Daily Performance (OIDP):

The Oral Impacts on Daily Performance (OIDP) questionnaire consists of 11-items focused on the impact of oral health on the performance of daily activities, such as eating, speaking, cleaning dentures, sleeping, showing teeth, emotional state, going out, enjoying social contact, feeling comfortable, relaxing and overall satisfaction. The satisfaction levels were scored on a scale from 1 to 5 (where 5 = great dissatisfaction, 4 = dissatisfaction, 3 = acceptance, 2 = satisfaction and 1 = strong satisfaction).

Statistical analysis:

It was performed using Statistical Package for Social Science (IBM SPSS) version 23 and Graph Pad Prism version 8.0.2. All data were explored for normality by checking the data distribution using Kolmogorov- Smirnov and Shapiro-Wilk test. All data were presented as mean, standard deviations. Paired t-test was used to compare between results of 1st & 3rd weeks, while the One Way ANOVA test was used to compare between different groups followed by Tukey's Post Hoc test for multiple comparisons. Moreover, Pearson's correlation coefficient was used to perform all needed correlations. The p-value was considered significant at $P \leq 0.05$.

Results:-

Dimensional changes were calculated in all groups after 1st week, and after 3rd week and presented as mean difference \pm standard deviation. Comparison between dimensional changes after 1st & 3rd week was performed by using Paired t-test which revealed insignificant increase (expansion) in dimensional changes in Group I after 3rd week as $P > 0.05$ while revealed insignificant decrease (shrinkage) in dimensional changes in GII-A & GII-B after 3rd week as $P > 0.05$. On the other hand, there was a significant decrease (shrinkage) in GIII-A & GIII-B after the 3rd week as $P < 0.05$, as presented in table (1) and figure (2).

Also, comparison between all groups was performed by using One Way ANOVA test which revealed a significant difference between them after 1st and 3rd week, followed by Tukey's Post Hoc test for multiple comparisons which revealed that G-I exhibited the significantly least amount of dimensional changes (expansion) after 1st & 3rd week, followed by G-II (shrinkage) with insignificant difference between GII-A & GII-B after 1st & 3rd week, finally G-III (shrinkage) which exhibited the largest amount of dimensional changes with insignificant difference between GIII-A & GIII-B after 1st week, while after 3rd week GIII-B exhibited the significantly highest amount of dimensional changes (shrinkage) as $P < 0.05$, as presented in table (1) and figure (2).

Oral health impact on daily performance (OIDP) among all groups was calculated after 1st week & 3rd week. Comparison between different intervals revealed that OIDP insignificantly decreased (an insignificant increase of means) in all groups except GIII-B as OIDP significantly decreased (significant increase in means), as presented in table (2) and figure (3).

Also, comparison between all groups revealed insignificant difference ($P > 0.05$) between them after 1st week, while after 3rd week there was a significant difference ($P < 0.05$) between them as G-I revealed significantly the best OIDP (significantly the lowest mean), while GIII-B revealed the worst OIDP (significantly the highest mean), as presented in table (2) and figure (3).

Correlation between oral health impact on daily performance (OIDP) and dimensional changes was performed by using Pearson's correlation coefficient which revealed moderate ($0.3 < r < 0.6$), significant ($P < 0.05$), positive (+) correlation in all groups as presented in table (3).

Table (1):- Dimensional changes (mean difference \pm standard deviation) after 1 week and after 3 weeks all groups:

Group	N	After 1 st week		After 3 rd week		P value (Paired t-test)	
		MD	SD	MD	SD		
GI (Sodium hypochlorite)	8	0.11 ^a	0.05	0.17 ^a	0.09	0.12	
GII Microwave once / week	GII-A (Dry)	8	- 2.51 ^b	0.82	- 2.95 ^b	1.11	0.38
	GII-B (Distilled water)	8	- 3.11 ^b	1.12	- 3.95 ^b	1.32	0.19
GIII	GIII-A (Dry)	8	- 4.12 ^c	1.15	- 5.99 ^c	2.17	0.04*

Microwave twice / week	GIII-B (Distilled water)	8	- 6.51 ^c	1.18	- 8. 21 ^d	1.53	0.01*
P value (ONE WAY ANOVA)			<0.0001*		<0.0001*		

MD: mean difference SD: standard deviation

*Significant difference as $P < 0.05$

Mean differences with the same superscript letters in the same column were insignificantly different as $P > 0.05$

Mean differences with different superscript letters in the same column were significantly different as $P < 0.05$

Table (2):- Mean and standard deviation of overall Oral Health Impact on Daily Performance (OIDP) among all groups after 1 week and after 3 weeks:

Overall (OIDP)		After 1 week		After 3 weeks		P value (Paired t-test)
		M	SD	M	SD	
GI (Sodium hypochlorite)		41.6 ^a	6.1	43.1 ^a	6.2	0.42
GII Microwave once / week	GII-A (Dry)	41.8 ^a	6.6	45.8 ^b	8.8	0.32
	GII-B (Distilled water)	42.4 ^a	7.6	47.2 ^b	8.9	0.26
GIII Microwave twice / week	GIII-A (Dry)	42.1 ^a	7.8	47.8 ^b	9.1	0.21
	GIII-B (Distilled water)	41.3 ^a	6.1	55.2 ^c	6.3	0.04*
P value (ONE WAY ANOVA)		0.91		0.04*		

MD: mean difference SD: standard deviation

*Significant difference as $P < 0.05$

Mean differences with the same superscript letters in the same column were insignificantly different as $P > 0.05$

Mean differences with different superscript letters in the same column were significantly different as $P < 0.05$

Table (3):- Correlation between Oral Health Impact on Daily Performance (OIDP) and Dimensional changes in all groups:

Group		r	P value	Indication
GI (Sodium hypochlorite)		0.35	0.02*	Moderate / Positive / Significant
GII Microwave once / week	GII A (Dry)	0.38	0.01*	Moderate / Positive / Significant
	GII B (Distilled water)	0.40	0.006*	Moderate / Positive / Significant
GIII Microwave twice / week	GIIIA (Dry)	0.39	0.001*	Moderate / Positive / Significant
	GIIIB (Distilled water)	0.45	0.03*	Moderate / Positive / Significant

r: Pearson`s Correlation Coefficient

*Significant difference as $P < 0.05$

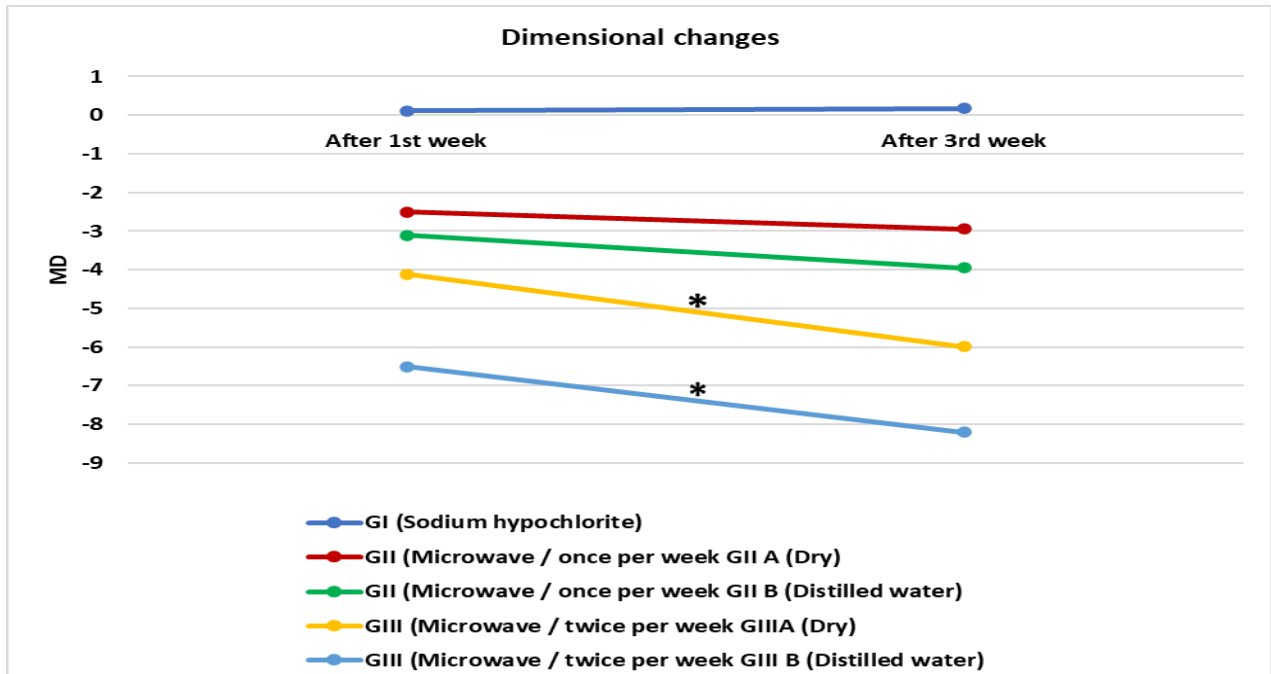


Figure (2):- Line chart representing dimensional changes in all groups after 1st week & 3rd week.

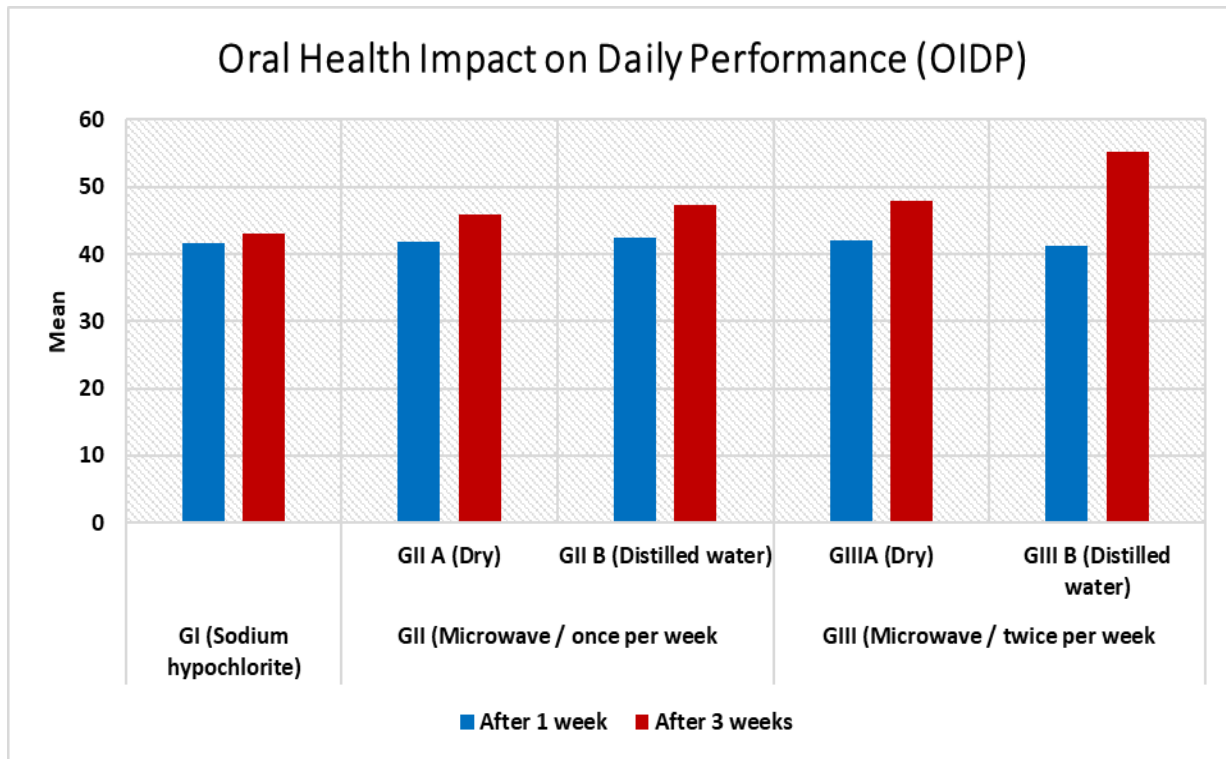


Figure (3):- Bar chart representing Oral Health Impact on Daily Performance (OIDP) in all groups after 1st week & 3rd week.

Discussion:-

Dimensional stability was critical for our study because heat-cured acrylic dentures revealed dimensional changes during disinfection procedures that greatly affect denture fitness, hardness, roughness, and overall patient satisfaction⁽¹⁵⁾.

In this study, 1% sodium hypochlorite was used as a control group as it is the safest, convenient, and inexpensive method. It is the commonly recommended chemical disinfectant for removable dental prostheses as the high temperatures should not be used to avoid denture base distortion. Moreover, 1% sodium hypochlorite group revealed the least dimensional changes in comparison with other groups, the current study was in agreement with other research which reported that heat-cured acrylic specimens showed small dimensional change after the disinfection process and were not of clinical status^(16,17).

These dimensional changes may be attributed to the water sorption that occurred when dentures are stored in water or in contact with oral fluids resulting in increased linear dimensional change, these results are in agreement with several studies that proved that all the disinfectants including water, induced linear expansion of the specimens. Although previous research assessed the efficiency of electromagnetic radiation disinfection on three different types of liners with soaked samples in water during radiation, they demonstrated that all soaked samples revealed constant disinfection regarding *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Bacillus subtilis*, and *Candida Albicans*^(18,19).

Though electromagnetic radiation for 6 minutes at 650W has been evidenced to be an effective protocol for acrylic resin disinfection, also it has a great consequence on the treatment of denture stomatitis and Candidiasis. Nevertheless, it has been detected that this procedure reduced the flexural strength of relining resin (chairside) and the surface hardness of different brands of acrylic resin denture teeth. Moreover, it was verified that increased disinfection duration to 10 minutes revealed significant discrepancies in the denture bases adaptation, accordingly in this study disinfection time was only 3 minutes to avoid physical and mechanical alteration of the denture^(10,20).

In this study, microwave disinfection either wet or dry exhibited dimensional changes (overall shrinkage) of denture bases which are expressive of the structural changes that happened inside the resin bases exposed to electromagnetic radiation protocol (650 W for 3 minutes) as heating of acrylic denture bases result in releasing of incorporated internal stresses during the processing which induced shrinkage in denture bases⁽²¹⁾.

Moreover, dimensional changes in dentures disinfected under wet condition was higher than in dry conditions. This was clarified by the boiling water (water starts to boil after 90 sec of radiation) elevates the temperature of the denture base, which in turn causes the residual monomer transformation into the polymer, which in agreement with the previous study that verified that water started to evaporate during electromagnetic radiation disinfection. This results in the dispersion of residual monomer molecules into the dynamic sites of the polymer chain. Due to this, there might be additional polymerization which leads to linear dimensional change (shrinkage) of denture bases⁽²²⁾.

The electromagnetic radiation disinfection in dry conditions resulted in minor shrinkage as proved in another study which revealed that acrylic rectangular specimens which experienced dry disinfection revealed minor dimensional changes (-0.005 to 0.009%). Also, it was reported that a little shrinkage up to 0.03% in cylindrical specimens after a 15-minute at 650 W microwave disinfection occurred^(9,23).

Additionally, in this study, we delivered new complete dentures to all patients to improve their quality of life and to evaluate the conventional disinfection method and compare it with electromagnetic radiation regarding their effect on patients' comfort as a different disinfection method⁽²⁴⁾.

Concerning Oral health impact on daily performance (OIDP), an obvious decrease has been recorded after 3rd week of denture disinfection. In group I, Group II-A, Group II B & GIII A there was an insignificant decrease in OIDO in comparison to OIDP after 1st week, while in GIII B there was a significant difference between 1st & 3rd-week regarding OIDP. Moreover, the correlation between OIDP and dimensional changes was performed and revealed a moderate, positive, significant correlation which explained the results of OIDP⁽²⁵⁾.

Conclusion:-

Within the limitations of this study regarding dimensional stability change and patient satisfaction of denture disinfection method used, it could be concluded that:

1. Complete denture treatment with sodium hypochlorite preparation showed the least dimensional changes with the highest patient satisfaction. Groups utilizing electromagnetic radiation treatment (microwave) showed higher dimensional changes with lower patient satisfaction.
2. Repeated exposure to electromagnetic radiation increased the incidence of dimensional changes.

3. Exposure to electromagnetic radiation in wet conditions increased the dimensional changes as compared with dry conditions.

Conflicts of interest

There are no conflicts of interest to be declared.

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