An In Vitro Study Evaluating The Effect Of Addition Of Carbon Nanotubes On Linear Dimensional Change Of Heat - Polymerized Denture Base Resin

Pankti Naik*, Somil Mathur,**

*Post graduate student, **Professor and Head of Department, Department of Prosthodontics, Crown and Bridgework and Oral Implantology, Faculty of Dental Science, Dharmsinh Desai University, Nadiad, Gujarat.

Abstract: Objective: To compare the linear dimensional change occurring between the antero-posterior and medio-lateral reference points marked on the heat- polymerized denture base resin between two groups formed with and without the addition of multi-walled carbon nanotubes in the posterior palatal seal region and mid palatine area on maxillary edentulous brass model. Method: Standard edentulous maxillary brass model, with 4 reference points [at incisive papilla (A), mid-palatal area in front of posterior palatal seal region (B), left and right tuberosities (C and D)] was made to fabricate a total of 10 denture bases. On the model, wax templates in the shape of posterior palatal seal (PPS) and mid palatine raphe were made to standardize the quantity of modified material incorporated in the PPS area and the mid palatine area i.e. acrylic mixed with 1 wt% of carbon nanotube. A control group with no incorporation of the modified material was also created. After denture base fabrication with incorporated modified material, the antero-posterior and the medio-lateral distance, between points A and B and points C and D, was measured with Digital Vernier Caliper and compared with the control group. Results: There was statistically significant difference found between the control and the incorporated carbon nanotube group when compared using unpaired t-test. Conclusion: Addition of carbon nanotubes in denture base acrylic resin showed significant linear dimensional change for this study. [Pankti N NJIRM 2017; 8(2):65-68]

Key Words: carbon nanotubes, acrylic, linear dimensional change

Author for correspondence: Pankti Naik, Department Of Prosthodontics, Crown & Bridgework and Oral Implantology, Faculty of Dental Science, Dharmsinh Desai University, Nadiad, Gujarat. M: 9725503864
E- Mail: panktinaik.pn@gmail.com

Introduction: Complete dentures in prosthetic dentistry, not only rehabilitate the lost form and function of hard and soft tissues, but also induce a firm background in restoring emotional and psychological wellbeing of the patient. A successful complete denture must restore the form and function as well as the health of the supporting and surrounding tissues with an improved aesthetic quotient for the patient. A well fitted denture promotes chewing efficiency, patient's comfort, preserves the remaining hard and soft tissues of oral cavity as well as prevents the development of any pathology.

Various materials such as polymethyl methacrylate, triethyleneglycol dimethacrylate, urethane dimethacrylate and hydroxyethyl methacrylate have been studied and used for denture base fabrication. Polymethyl methacrylate, however, is the material of choice for fabrication of denture base resins. The introduction and use of acrylic resins as denture base materials since 1937 has revolutionized dentistry in a big way and for the better. The resin has fine esthetic properties, is excellent in color and is chemically stable.

However, the dimensional changes of acrylic resins are proven to be inevitable, which are said to be caused by processing shrinkage and expansion upon water sorption.[1] In addition to the volumetric shrinkage, linear shrinkage causes significant effects upon the denture adaptation and cuspal interdigitation. The greater the linear shrinkage, the greater is the discrepancy observed in the initial fit of a denture.[2] Reported linear shrinkage values range from 0.26% to 1.20% but are considered approximately to be 0.5% for heat-processed acrylic resins.[3] Acrylic resin dentures are also notable for their tendency to absorb water which causes corresponding dimensional change.[4]

In order to overcome these short comings, various materials such as synthetic fibers, metallic wires and rubber toughning agents have been incorporated in the acrylic resin to improve the mechanical properties and to reduce the shrinkage.[5] According to Wong et al (1999) carbon nanotubes were regarded as the best reinforcement material in resins.[6]

Carbon nanotubes are macromolecular form of carbon and considered as a class of nanomaterials, with high potential of biological applications due to their mechanical, physical and chemical properties. They have large surface area and ultra-light weight. They are basically structures of single or multiple sheets of graphene rolled up to form single-walled and multi-

walled carbon nanotubes. In nanotubes, the carbon atoms arrange themselves in hexagonal rings and a strong bond exists between carbon atoms which makes them very stable, however their only drawback is the high cost and dark color.[7]

Considering the importance of dimensional changes occurring during the processing and the promising properties of carbon nanotubes, the present study will strive to evaluate and compare the linear dimensional change of heat-polymerized denture base resins reinforced with and without carbon nanotubes.

Methods: This research was conducted in the Department Of Prosthodontics, Crown And Bridgework and Oral Implantology, Faculty Of Dental Science, Dharmsinh Desai University, Nadiad, Gujarat. The approval of the Ethical Committee was obtained prior to the commencement of the study.

A brass edentulous maxillary model was fabricated with four reference points marked at incisive papilla (A), mid-palatal area in front of posterior palatal seal region (B), left and right tuberosities (C and D).

2 groups containing 5 specimens each were defined as:
Group 1: heat polymerized denture base resins, without addition of carbon nanotubes (control group).
Group 2: heat polymerized denture base resins, with addition of 1wt% carbon nanotubes in the posterior palatal seal region and mid palatine region.

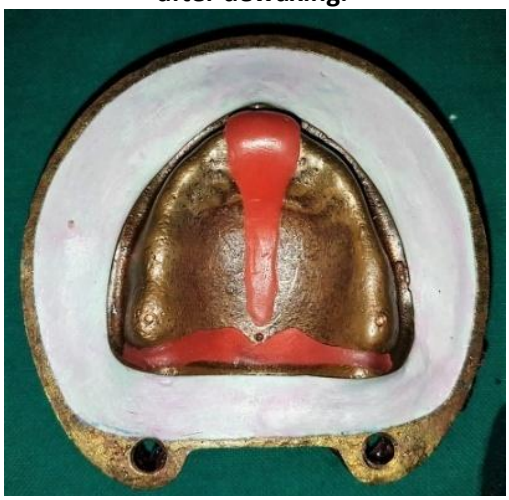
To prepare the specimens of group 1, 1.5mm thick modelling wax (Y-Dent, MDM Corporation, Lalkuan, Delhi, India) was adapted on the maxillary brass model and the whole assembly was invested in a universal flask (Gibbling bros, Unident, Victoria, Australia). After subjecting them to dewaxing, packing of the mold with heat-polymerized acrylic resin (lucitone 550, Dentsply International, Inc., York, PA, Canada) in dough stage was achieved. The manipulation of the material was done as per the manufacturer's instruction.

To prepare the specimens of group 2, first of all, multi-walled carbon nanotubes (multi-walled carbon nanotubes with COOH functionalized group, Purity: >97%, Diameter: >30 nm, Length: 10-20 µm) were subjected to ultrasonic agitation in an ultrasonic unit for uniform dispersion of carbon nanotubes in the monomer (methyl methacrylate). Care was taken to prevent agglomeration of carbon nanotube particles. Then, before the preparation of the denture base specimens, a standard self-cure acrylic template in the shape of posterior palatal seal and mid palatine region was made to standardize the quantity of modified material incorporated in the respective areas and wax templates were fabricated by duplicating the acrylic template (illustration 1).

Illustration 1: self-cure acrylic templates in PPs and mid palatine region and duplicated in wax

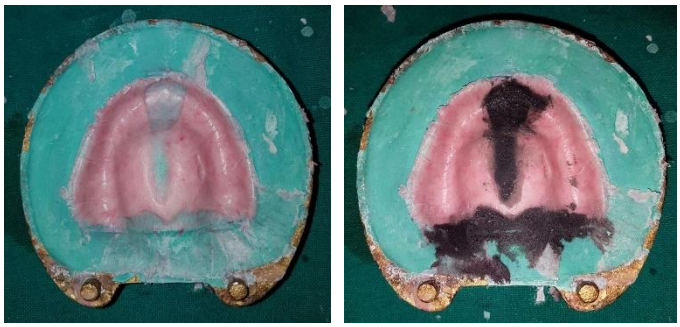
To prepare denture base specimens for group 2, again 1.5 mm thickness of modelling wax was adapted on the model. This was invested in a flask and dewaxing procedure was carried out in a conventional manner. After dewaxing, the prefabricated wax templates were seated in the posterior palatal seal region and mid palatine region of the model (illustration 2). Heat cure acrylic resin in dough stage, was packed. The manipulation was done as per the manufacturer's instruction.

Illustration 2: wax templates placed on the model after dewaxing.



The wax templates were then removed after the trial closure and in the space thus created, heat cure acrylic resin premixed with 1wt% multi-walled carbon in the monomer is packed and the flask is reassembled.

Illustration 3: packing of carbon nanotubes at the time of trial closure.



Curing was done using conventional curing cycle (75^0C for 2 hours followed by 97^0C for 1 hour). Deflasking was done an hour after the curing cycle is completed. The reference points marked on the brass model were thus transferred to the intaglio surface of the denture bases. The dimensions between the reference points were measured immediately after deflasking while the specimens were in the raw form, without doing any finishing or polishing of the surfaces.

The measurement of dimensions between the marked reference points (AB and CD), for both group 1 and group 2 specimens and for the brass edentulous maxillary model, was done using a digital vernier calliper (Safeseed, Delhi, India) and by two operators who did not know the purpose of the study. Comparison of the dimensions of the two groups as well as those of each group and those on the brass model was carried out. The results were tested statistically using Student's unpaired t-test.

Result: The mean values and standard deviations of antero-posterior and medio-lateral distance of all the specimens are shown in table 1 and table 2.

Table:1 Comparison of antero-posterior distance (A-B)between group 1 (control) and group 2

	Group 1		Group 2	
	Mean	**SD**	**Mean**	**SD**
Specimen 1	41.2	0.05	41.5	0.05
Specimen 2	41.3	0.05	41.4	0.10
Specimen 3	41.3	0.05	41.4	0.11
Specimen 4	41.2	0.11	41.4	0.11
Specimen 5	41.2	0.05	41.4	0.11

Table: 2 Comparison of medio-lateral distance(C-D) between group 1 (control) and group 2

	Group 1		Group 2	
	Mean	**SD**	**Mean**	**SD**
Specimen 1	40.8	0.05	41.1	0.05
Specimen 2	40.9	0.15	41.1	0.05
Specimen 3	40.8	0.05	41.0	0.05
Specimen 4	40.9	0.15	41.1	0.05
Specimen 5	40.9	0.15	41.1	0.05

Statistically significant difference ($p<0.05$) was observed between the control and carbon nanotube group when the distance between the reference points A and B was measured using digital Vernier caliper.

Statistically significant difference ($p<0.05$) was also observed between the control and carbon nanotube group when the distance between the reference points C and D was measured using digital Vernier caliper in a similar fashion.

This indicates that there is a closer adaptation of the carbon nanotubes incorporated denture base in comparison to the conventional heat-polymerized denture base without any additional incorporated material.

Discussion: When methyl methacrylate monomer is polymerized to form polymethyl methacrylate, the density changes from 0.94 to 1.19 g/cm3. This change in density results in a volumetric shrinkage of 21%. The polymer contains prepolymerized polymethyl methacrylate. Therefore, this ratio reduces the amount of monomer that contributes to polymerization shrinkage and limits the value of shrinkage to approximately 7%. The shrinkage is further compensated by the restricting mould and water absorption property of PMMA. PMMA exhibits a water sorption value of 0.69 mg/cm2. Each 1% increase in weight produced by water absorption result in a linear expansion of 0.23%.[8] Also, the shrinkage is distributed uniformly to all surfaces resulting in satisfactory adaptation of denture base.

It is a known fact that polymerization shrinkage occurs in posterior region i.e. in posterior palatal seal area followed by the mid palatine region. Accurate adaptation of denture base in the regions is very important for the success of prosthesis especially in patients with extreme ridge resorption. By using acrylic

mixed with carbon nanotube selectively in the posterior region or mid palatine region, the polymerization shrinkage can be reduced along with maintaining the esthetics.

Carbon nanotubes have intrinsic property of adhesion with the polymer. This adhesion results in stress transfer from polymer to carbon nanotubes resulting in reduced dimensional changes.[9] It improves the fit of denture base.

Conclusion:

1. Addition of carbon nanotubes to the acrylic resin brings about a lesser dimensional change after the processing of the denture hence bringing out a closer adaptation of the denture base to the tissues

2. Major drawback of carbon nanotubes, however, is poor esthetics because of its dark colour. Hence, it can only be used in non ethetic zones.

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