Heat cure acrylic resin is the most popular denture base resin and its popularity can be attributed to the ease of manipulation, uncomplicated laboratory techniques, aesthetics and desirable biologic profile. But polymerization shrinkage is a major handicap and that can result in poor fit of the denture. Volumetric shrinkage of 7% and linear shrinkage of 0.43% have been reported. Metallic wires, synthetic fibres and rubber toughening agents have been incorporated in acrylic resin to improve the mechanical properties and to reduce shrinkage. Carbon nanotubes and graphene are the latest introduction to the field of reinforcement.

Carbon nanotubes are long thin cylinders of graphite made up of a layer of carbon atoms arranged in hexagonal lattice, held together by weak Van der waal forces. Tensile strength of carbon nanotubes ranges from...
Fig 1. Standard edentulous maxillary cast

Fig 2. Fabrication of acrylic template

Fig 3. Duplication of PPS template in wax

Fig 4. Adaptation of wax on cast

Fig 5. After dewaxing, wax template was placed in the PPS region

Fig 6. Packing of the denture base with wax template in the PPS region

Fig 7. Template was removed after the resin reached rubbery stage

Fig 8. Graphene / Carbon nanotube mixed in acrylic packed in the space

Fig 9. Trimmed cast with denture base

Fig 10. Gap was measured using stereomicroscope

Fig 11. Stereomicroscopic picture of the cast with the denture base
Young’s modulus ranges from 1.7-2.4 Tpa. Addition of 0.5 wt% carbon nanotubes in acrylic resins, increases flexural strength by 9.3% and resiliency by 16%. Carbon nanotubes also prevent shrinkage and dimensional changes during and after polymerization. Graphene is an allotrope of elemental carbon, a planar monolayer of carbon atoms arranged into a two-dimensional honeycomb lattice with a carbon-carbon bond length of 0.142 nm. Currently, it is considered as the strongest material available. Tensile strength of graphene is 130 Gpa. Modulus of elasticity and surface hardness of cured polymer significantly increased with small quantities of graphene. Addition of 0.011 wt% of graphene in polymer increased hardness by 12%. The effect of carbon nanotubes on polymerization shrinkage of acrylic resin has been evaluated, but not with graphene. Both the materials have undesirable color and hence it cannot be used for making the complete denture base. However this desirable property of lesser shrinkage can be utilized by incorporating it restrictively in the posterior palatal seal region. In this context it was decided to compare the effect of incorporating carbon nanotubes and graphene on polymerization shrinkage when it is used restrictively in posterior palatal seal region.

**Methodology**

Standard edentulous maxillary casts were made to fabricate different types of denture bases (Fig 1). These casts were divided into three groups on the basis of the different materials used. Group I served as control group where conventional heat cure acrylic resin was used. In

<table>
<thead>
<tr>
<th>Group (I)</th>
<th>Group (J)</th>
<th>Difference of mean (I-J)</th>
<th>p - value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>0.5 wt % Graphene</td>
<td>0.2900</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>0.5 wt % Carbon nanotube</td>
<td>0.3500</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>0.5 wt % Carbon nanotube</td>
<td>0.5 wt % Graphene</td>
<td>-0.0600</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>0.25 wt % Carbon nanotube</td>
<td>-0.1000</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>0.5 wt % Graphene</td>
<td>0.5 wt % Carbon nanotube</td>
<td>0.0600</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>0.25 wt % Graphene</td>
<td>-0.0800</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>0.25 wt % Carbon nanotube</td>
<td>0.125 wt % Carbon nanotube</td>
<td>-0.1300</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>0.25 wt % Graphene</td>
<td>0.125 wt % Graphene</td>
<td>-0.1300</td>
<td>0.0014</td>
</tr>
</tbody>
</table>
group II, carbon nanotube was added in heat cure acrylic resin and in group III, graphene was added along with heat cure acrylic resin. Group II and III were further subdivided into three subgroups A, B and C depending on the concentration of carbon nanotube or graphene used. Subgroup A was 0.5 wt%, B was 0.25 wt % and C was 0.125 wt % of carbon nanotube or graphene.

Before the preparation of the denture base specimen, standard wax templates in the shape of posterior palatal seal (PPS) were made to standardize the quantity of modified material incorporated in the PPS area. The wax templates were fabricated by duplicating an acrylic template made on cast. (Fig. 2, 3)

To prepare denture base, two sheet thickness of modelling wax was adapted on the cast (Fig 4). This was invested in a flask and dewaxing was done in a conventional manner. After dewaxing, the prefabricated wax template was sealed in the PPS region of the cast, and heat cure acrylic resin was packed (Fig 5, 6). The wax template was removed after the trial closure (Fig 7). In the space thus created, heat cure acrylic resin premixed with different concentrations of graphene and carbon nanotube was packed and flask was reassembled (Fig.8). Specimen for the control group was fabricated using same technique. Heat cure acrylic resin without any addition was packed in the space created by wax template. Curing was done using conventional curing cycle (75°C for 2 hours followed by 97°C for 1 hour).

After deflasking, cast and the denture base was removed in one unit. 5mm of the denture base was trimmed off in the posterior region (Fig 9). The gap between denture base and the cast was measured. Stereomaster microscope (Labovision, India) at 20x magnification was used to take the picture and software (Progress) was used to measure the gap between cast and denture base (Fig 10, 11).

Results
The mean values and standard deviations of all the groups are shown in Table 1. Results were statistically analyzed using Student t-test. When the gap between the cast and the denture base was evaluated, statistically significant difference was observed between control and carbon nanotube group, as well as, control and graphene group (p<0.0001) (Table 2). The groups containing carbon nanotube and graphene showed less gap between cast and denture base when compared to control group.

Statistically significant difference was observed when gap between denture base and cast was compared for carbon nanotube and graphene (p<0.0001). Carbon nanotube groups showed less gap between the cast and denture base when compared to graphene groups. The gap between the cast and denture base was least with 0.5% carbon nanotube group.

Statistically significant difference was also observed when different concentrations of carbon nanotube group or graphene group were compared (p<0.003). A reduction in the gap was observed when the concentration increased.

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%. Commercially available products generally suggest use of polymer to monomer ratio of approximately 3:1 by volume. 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%.

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. Accurate adaptation of denture base in this region is very important for the success of prosthesis especially in patients with extreme ridge resorption. By using acrylic mixed with carbon nanotube or graphene selectively in the posterior region, we can reduce the polymerization shrinkage and can maintain the esthetics also. 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. It improves the fit of denture base.

Conclusions
1. Addition of carbon nanotubes and graphene in denture base acrylic resin showed reduction in polymerization shrinkage.
2. Polymerization shrinkage was least with the addition of 0.5 wt% of carbon nanotube. Further reduction in the quantity of both agents reduces the effectiveness in counteracting the shrinkage.
3. Major drawback of carbon nanotubes and graphene is poor esthetics because of its dark colour. Hence it can be used only in non aesthetic zone.

References
7. www.scientistlive.com/content/22903 Nanotechnology : Promising uses for graphene

Trends in Prosthodontics and Dental Implantology (TPDI)

Subscription Form

Rs. 300 per issue, Rs. 600 for 1 Year (2 issues), Rs. 1200 for 2 years (4 issues)

Name ...........................................................................................................................................................................
Address ..........................................................................................................................................................................
...................................................................................................................................................................................
State: ........................................Pin Code ......................................................................................................................
Tel. No......................................E-mail ....................................................................................................................

Kindly find here with enclosed D.D. no...... dated.......... of................. Bank for Rs.........................
in favour of Dr. Lakshmikanth K payable at Bangalore

All correspondence may please be sent to the following address:
The Editor, Dept. of Prosthodontics, AECS Maaruti College of Dental Sciences and Research Centre
108, BTM 6th stage, I Phase, Hulimavu Tank Bund Road, Off Bannerghatta Road, Bangalore - 560076
Tel: 09448064349 / Fax: 080-26587159 / E-mail: trendsinprosthodontics@gmail.com