

# Effect Of Radiotherapy On Modulus Of Elasticity Of Luting Cements- An In Vitro Study

Dr Palak Abhishek Pandya <sup>1</sup>, Dr Rajeshwari CL<sup>2</sup>, Dr Tanveer Pasha<sup>3</sup>, Dr Rohit M Shetty<sup>4</sup>, Dr Srivatsa G<sup>5</sup>, Dr Zeel Makwana<sup>6</sup>

<sup>1</sup>Senior lecturer, Department of Prosthodontics, Karnavati School of dentistry, Uvarsad, Gujarat. India.

<sup>2</sup>Assistant Professor, Department of Prosthodontics, KLE's society's institute of dental sciences, Bangalore. India. Email- clrajeshwari@yahoo.com

<sup>3</sup>Professor, Department of Oncology, Kidwai memorial institute of Oncology, Bangalore. Email- drtanvirpasha@gmail.com

<sup>4</sup>Head of the department, Department of Prosthodontics, KLE's society's institute of dental sciences, Bangalore. India. Email- rohitmohanshetty@gmail.com

<sup>5</sup>Professor & Principal, Department of Prosthodontics, KLE's society's institute of dental sciences, Bangalore. India. Email- drsrivatsa.g@gmail.com

<sup>6</sup>Intern, Department of Prosthodontics, Karnavati School of dentistry, Uvarsad, Gujarat. India. Email- zeelmakwana123@gmail.com

Corresponding author-

Dr Palak Abhishek Pandya,

Senior lecturer, Department of Prosthodontics, Karnavati School of dentistry, A/907, Adalaj-Uvarsad Road, Gandhinagar, Gujarat 382422, India. Email id- palak@karnavatiuniversity.edu.in

DOI: 10.47750/pnr.2022.13.S06.578

## Abstract

**Aim-** The aim of the study was to evaluate changes in modulus of elasticity of luting cements due to radiotherapy. **Materials and Methods-** Total of 90 rectangular specimens of 25×2×2 mm dimension were fabricated by utilizing the putty consistency polyvinyl siloxane rubber mould. They were grouped based on their type. Group A had 30 specimens made of zinc phosphate luting cement, Group B had 30 specimens fabricated using glass ionomer luting cement, and Group C had 30 specimens fabricated using resin luting cement. After 24 hours of storing the specimens in distil water, 15 from each group of the mentioned cements were subjected to fractional irradiation upto 60 Gy by a Cobalt-60 external beam machine. Remaining specimens from each group were used as controls. After radiotherapy, the specimens were stored in distil water for 24 hours until performing the 3 point bend test. Flexural strength values were obtained, using which modulus of elasticity of each specimen was assessed. Statistical Examination- Kruskal Wallis Test followed by Mann Whitney test was used to compare the mean values of different parameters between three groups of Irradiated and controlled samples. The level of significance was set at P<0.05. **Results-** After exposure to fractional irradiation for 4 weeks, in the zinc phosphate luting cement (Group-A) and resin luting cement (Group-C) showed a increase in modulus of elasticity. The glass ionomer luting cement (Group-B), showed decrease in modulus of elasticity. **Conclusion-** Among all, resin and zinc phosphate luting cement showed increase in flexural strength when compared to glass ionomer cement after fractional irradiation.

**Keywords -** luting cements, modulus of elasticity, head and neck cancer, radiotherapy, fractional irradiation.

**DOI: 10.47750/pnr.2022.13.S04.001**

## Introduction

The success of the prosthesis is measured mainly based on the type of luting cement used for cementation and the technique of cementation. Broad categories of luting cements are available which help in forming a stable interface between the prosthesis and the tooth.

Among all the luting cements available, no particular cement exhibits the ideal properties<sup>1</sup>. Luting cement needs to exhibit favourable compressive strength, tensile strength, modulus of elasticity, fracture toughness, durable bond strength, resistant to disintegration in the oral cavity etc. in order to bear occlusal load and prevent frequent adhesive failures of prosthesis<sup>2</sup>.

Among all the properties mentioned, modulus of elasticity indicates resistance to cement deformation and to marginal gap formation. The favourable value of modulus of elasticity of a luting cement should be between that of dentin and the prosthesis material.<sup>3</sup> This is affected by many factors.

One of the factors is radiotherapy which is common mode of treatment among the patient's having head and neck cancer. It accounts for more than 550,000 cases annually worldwide.<sup>4</sup> It is the six-th prevalent cancer site with a survival rate of 50% over 5 years.<sup>5</sup> Most common treatment modalities of this cancer includes surgical excision and radiotherapy. Side effects of radiotherapy are very much known. They are oral mucositis, xerostomia, irradiation caries, fibrosis of blood vessels and soft tissues, osteoradionecrosis.

Many studies have reported effect of radiation treatment on the physical and chemical changes in enamel, dentin and type of restorative cements used.<sup>6,7,8</sup> But the research in the field of luting cements is still unknown. The changes in the mechanical properties luting cement due to irradiation needs to be evaluated in order to help us in deciding the best cement used for cementation of prosthesis among head and neck cancer patients undergoing radiotherapy.

Thus the following study has been undertaken, to assess modulus of elasticity three luting cements: Zinc phosphate, glass ionomer cement and resin cement with a null hypothesis that there no effect of radiotherapy on the modulus of elasticity of the mentioned luting cements. An alternate hypothesis was formulated that there would be changes in the modulus of elasticity of luting cements after subjecting them to radiotherapy.

### Materials and Methods

A total of 90 test samples were fabricated with dimensions of 25mm length, 2mm width and 2mm thickness(Fig. 2,3,4) as per International Standardization Organization (ISO) by utilizing the putty consistency polyvinyl siloxane rubber mould (putty impression material, Aquasil, Densply). These specimens were fabricated and grouped based on the materials used as,(Table No. 1, Fig. 1)

All the cements were mixed according to manufacturer's instructions and were allowed to set in rubber mould covered with a cellophane sheet between two glass microscope slides at room temperature. Once the specimens were set, they were maintained in distilled water between the experiments. After 24 hours, 15 from each group of the mentioned cements were subjected to irradiation fractionally upto 60 Gy by a Cobalt-60 external beam machine (Theratron – E1) with field size of 35 X 35 cm<sup>2</sup>, depth was kept to the tray level, source to tray distance was maintained with 56 cm, with output factor of 1.051, Average energy output of the machine- 1.25 Mev and with a total of four doses (15 Gy/day) at different time intervals based on the value of output. (Table no. 2, Fig. 5). Other remaining rectangular specimens were used as control and stored in distilled water (Mysore RES-CHEM laboratories) until the tests were performed.

After radiotherapy, the specimens were stored in distil water for 24 hours until performing the 3 point bend test. All the 90 rectangular test specimens including control were subjected to 3 point bend test on Universal Testing machine for checking flexural strength. Based on the values obtained from flexural testing, modulus of elasticity was determined by the formula.

Flexural strength:

$$F = 3P_f L / 2WH^2$$

Where  $P_f$  is the measured maximum load at the time of specimen fracture,

$L$  is the distance between the supports on the tension surface (20 mm),

$W$  is the mean specimen width,

$H$  is the mean height of the specimen between the tension and compression surfaces

Modulus of elasticity:

$$E = (\Delta F / \Delta Y) \times (L^3 / 4WH^3)$$

Where  $\Delta F / \Delta Y$  is the change in force ( $\Delta F$ ) per unit change in deflection of the centre of the specimen ( $\Delta Y$ ),

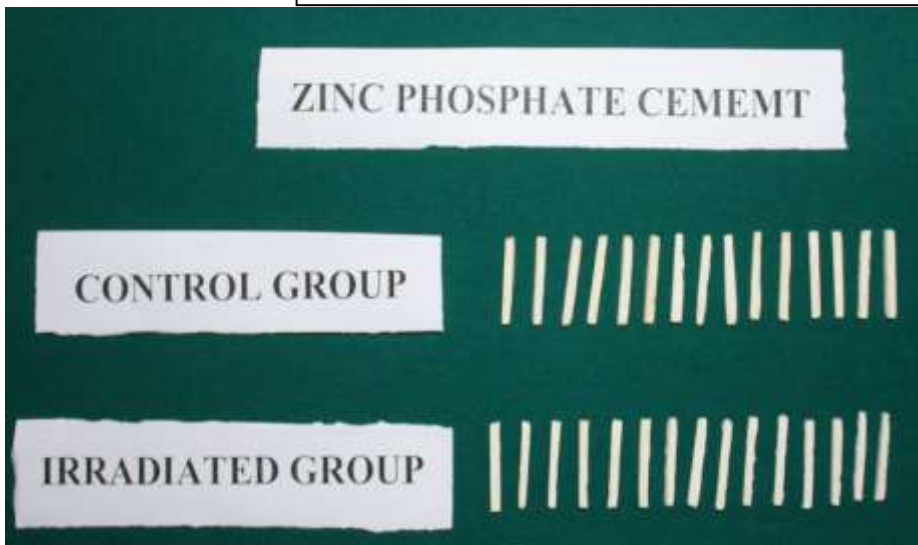
$L$  is the distance between the supports on the tension surface (20 mm),

$W$  is the mean specimen width,

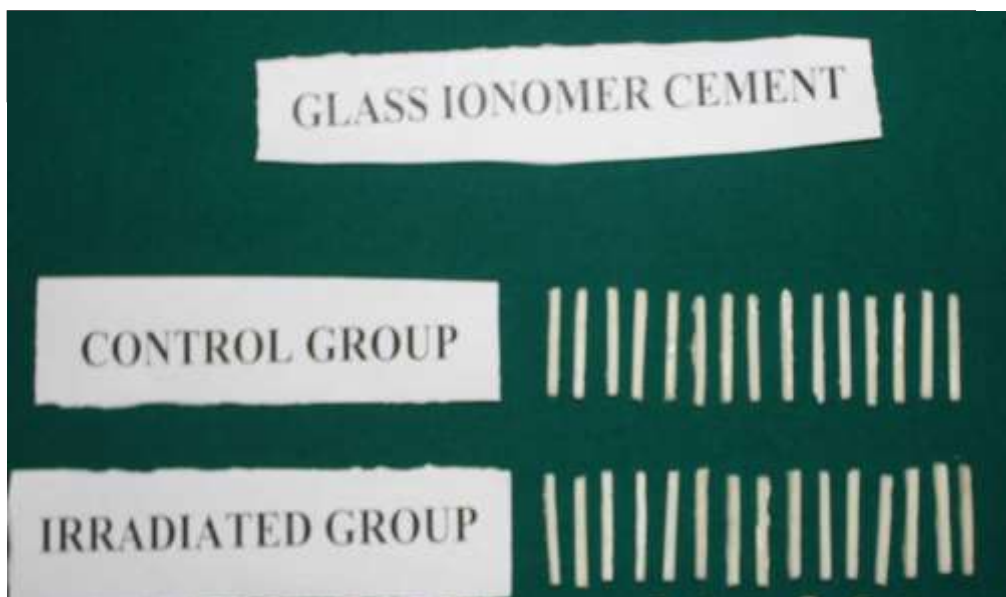
$H$  is the mean height of the specimen between the tension and compression surfaces.



**Fig.1 Luting cements used in the study**



**Fig.2 Rectangular specimens of zinc phosphate luting cement**



**Fig.3 Rectangular specimens of glass ionomer luting cement**



**Fig.4 Rectangular specimens of resin luting cement**



**Fig.5 Cobalt-60 external beam machine (Theratron – E1)**

**Table 1- List of luting cements used in the study**

Groups	Type of Cement	Brand Name	P/L Ratio	Batch No	Manufacturer	Sample Size
A	Zinc Phosphate	Harvard	3:1	1111504	Harvard Luting Cement, America	30
B	Glass Ionomer Cement	G C Gold Label	3:1	1703151	GC Gold Label Luting and Lining, America	30
C	Resin Cement	Calibra	2.25:1	160723	Dentsply, Germany	30

**Table no. 2: Total irradiation exposure time for the specimens**

Weeks	Treatment time	Fractional Dose (Total dose- 60 Gy)
1 <sup>st</sup> week	4 min 53 sec	15 Gy
2 <sup>nd</sup> week	4 min 54.6 sec	15 Gy
3 <sup>rd</sup> week	4 min 55.2 sec	15 Gy
4 <sup>th</sup> week	4 min 58.2 sec	15 Gy

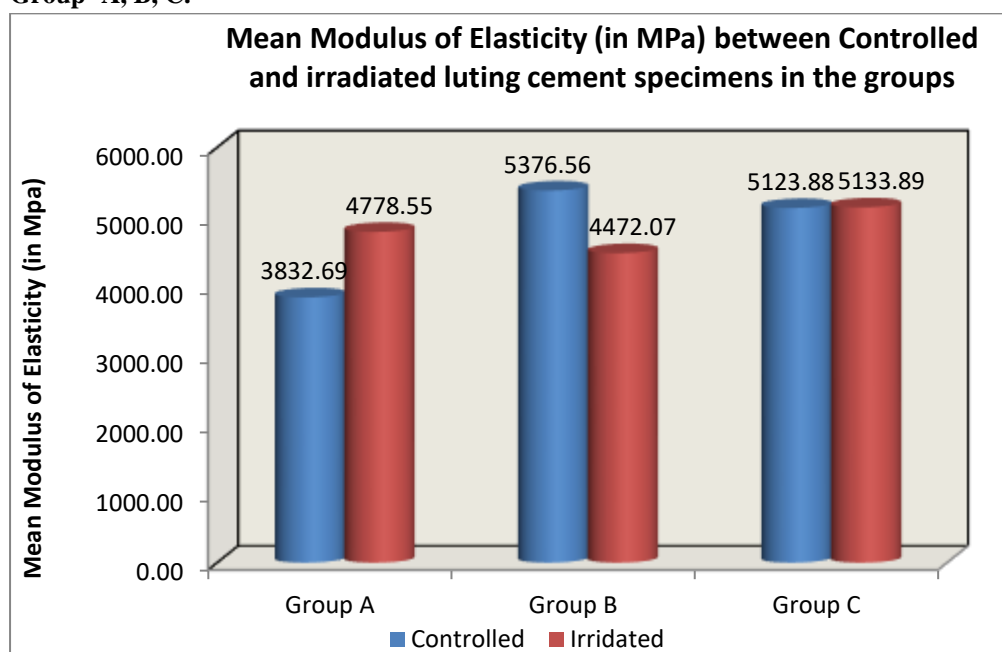
**TABLE.3: Mean, Standard Deviation, P-values of Modulus of Elasticity (MPa) between Irradiated and Controlled specimen in the Group- A, B, C using Mann Whitney U Test**

Parameters	Samples	N	Mean	SD	Mean Diff	P-Value
Group-A	Controlled	15	3832.69	277.00	945.86	0.02*
	Irradiated	15	4778.55	1361.26		
Group-B	Controlled	15	5376.56	763.78	-904.49	0.01*
	Irradiated	15	4472.07	1101.48		
Group-C	Controlled	15	5123.88	840.10	10.01	0.76
	Irradiated	15	5133.89	777.81		

**Table-4: Mean, Standard Deviation, Minimum, Maximum, P-values of Modulus of Elasticity (MPa) between Group- A, B, C including Controlled & Irradiated specimens using Kruskal Wallis Test followed by Mann Whitney Post hoc Analysis**

Parameters	Groups	N	Mean	SD	Min	Max	P-Value	Sig. Diff	P-Value
Modulus of Elasticity (MPa) Controlled specimen	A	15	3832.69	277	3345	4346.2	<0.001*	A Vs B	<0.001*
	B	15	5376.56	763.78	4537	7272.7		A Vs C	<0.001*
	C	15	5123.88	840.1	3759.4	6750		B Vs C	0.31
Modulus of Elasticity (MPa) Radiated specimen	A	15	4778.55	1361.26	2478.1	7044.1	0.11	A Vs B	0.63
	B	15	4472.07	1101.48	2619.6	7062.5		A Vs C	0.27
	C	15	5133.89	777.81	3130.4	6176.7		B Vs C	0.09

**Graph. 1: The mean Modulus of elasticity (MPa) of controlled and irradiated luting cement specimens in Group- A, B, C.**



## Results

Statistical Package for Social Sciences [SPSS] for Windows Version 22.0 Released 2013. Armonk, NY: IBM Corp., was used to perform statistical analyses.

### Descriptive Statistics:

Descriptive analysis included expression of study parameters in terms of Mean and SD.

### Inferential Statistics:

Kruskal Wallis Test followed by Mann Whitney test as post hoc analysis (Table. 4) was used to compare the mean values of different parameters between three groups of Irradiated and controlled samples. Mann Whitney U Test (Table. 3) was used to compare the mean values of different parameters between Irradiated and Controlled samples with respect to different cement groups.

The level of significance was set at  $P < 0.05$ .

Mann Whitney U Test showed statistically significant ( $P < 0.01$ ) results among irradiated and radiated specimens of Group A and B (Table. 3).

The modulus of elasticity (MPa) among the groups-A, B, C of controlled specimens were found to be statistically significant ( $P = 0.001$ ) as per Kruskal Wallis test and in irradiated specimens among the groups, the modulus of elasticity showed statistically non-significant results ( $P = 0.11$ ).

Mann Whitney Post hoc Analysis was applied between the two groups (Table. 4 and Graph 1), it was found to be statistically significant ( $P = 0.001$ ) for ZnPO<sub>4</sub> with GIC and ZnPO<sub>4</sub> with resin in controlled specimens whereas the rest of the groups showed non-significant difference i.e., resin and GIC controlled specimens ( $P = 0.31$ ), ZnPO<sub>4</sub> and GIC irradiated specimens ( $P = 0.63$ ), ZnPO<sub>4</sub> and resin irradiated specimens ( $P = 0.27$ ), GIC and resin irradiated specimens ( $P = 0.09$ ). The modulus of elasticity of resin luting cement was better followed by ZnPO<sub>4</sub> and GIC after fractional irradiation.

## Discussion

Luting cements require desirable mechanical and physical properties to resist adhesive or cohesive failure of the prosthesis. Favourable compressive, tensile strengths and sufficient fracture toughness, adequate film thickness and viscosity ensure longitivity of the fixed prosthesis. Among these, flexural strength, modulus of elasticity, compressive strength and are some of the important mechanical properties of luting cement.<sup>1,2,4,16,17</sup> If the clinical situation is altered like, people undergoing radiotherapy then choice of luting cement for a fixed prosthesis is questionable. Studies have shown significant changes in the restorative materials due to irradiation and significantly affecting the stability and longevity of restorations.<sup>6,7,8,13,18,19,20</sup> Thus the following study was undertaken, to assess effect of irradiation on modulus of elasticity of three luting cements: Zinc phosphate, glass ionomer and resin.

Rectangular bar-shaped luting cement specimens (45 control and 45 irradiated) were fabricated as per ISO standardisation-4049 and were subjected to 3 point bend test to check for modulus of elasticity. The specimens were divided equally into 3 groups: Group-A (ZnPO<sub>4</sub>), Group-B (GIC), Group-C (Resin). The specimens were subjected to fractional irradiation of 60 Gy by total of four doses (15 Gy/day)<sup>9</sup> except for the control rectangular specimens. Distilled water at room temperature was used as a media to store the control and the irradiated specimens in between the fractional dose exposure, so that it reproduces the condition of moisture present in the oral cavity.<sup>10</sup> This was done in order to simulate the oral cavity in order to provide reliability of the results. Based on the values obtained from flexural strength, modulus of elasticity was calculated for each of the luting cement specimen using the formula.

The mean modulus of elasticity of controlled specimens of ZnPO<sub>4</sub> group was 3832.69 MPa (3.83 GPa) and for the irradiated specimens was 4778.55 MPa (4.78 GPa). The increase in modulus of elasticity in this group was statistically significant ( $P = 0.02$ ) after irradiation as per Mann Whitney U test (Table- 4, Graph-2). Though the ideal values are 13.5 GPa,<sup>11</sup> the obtained values of our present study are lesser and this could be due to testing of the specimens after immersion in distilled water after 4 weeks.

The mean modulus of elasticity value of controlled GIC luting cement after 4 weeks of storage in distilled water was 5376.56 MPa (5.38 GPa). The mean modulus of elasticity of irradiated specimens was 4472.07 MPa (4.47

GPa) (Graph-1). There was a decrease in modulus of elasticity ( $P=0.01$ ) after radiotherapy which was found to be statistically significant as per Mann Whitney U test (Tables- 3, 4). Based on the study conducted by Cheung et al.<sup>12</sup> gamma radiation disrupts glass ionomer cement matrix by breaking the chemical bonds. Another study done by Novias V R et al.<sup>10</sup> showed similar results where there was significant reduction in diametral tensile strength and increase in hardness values for restorative GIC due to gamma irradiation. Maximum alteration the mechanical properties of glass ionomer cement was reported due to fractional irradiation. On the basis of Yesilyurt C et al.,<sup>6</sup> in their study stated that irradiation seems to interfere with the chemical adhesion of restorative GIC to dentin which could also result decrease in modulus of elasticity.

Contrary to our study results, Brandeburski SBN et al.<sup>13</sup> observed increase in mean flexural strength and diametral tensile strength values for glass ionomer cements after irradiation. These results may be partially explained by Cruz A et al,<sup>14</sup> who has observed that gamma irradiation induce molecular excitation and further significantly promote polymerization reaction by improving cross-linking between ions. This may explain the significant increase in strength of GIC cement.

Among resin luting cement, the mean value of modulus of elasticity of controlled resin specimens was 5123.88 MPa (5.123 GPa) whereas for irradiated specimen it was increased to 5133.89 MPa (5.133 GPa), which was statistically non-significant ( $P=0.76$ ) as per Mann Whitney U test. (Table-4 and Graph-1). This could be explained by the study done by Hegde et al.<sup>15</sup> that the gamma irradiation promotes high degree of polymerization in the matrix by altering the chemical bonds which resulted in increased micro-hardness of the composite material. This might be the reason for a slight increase in modulus of elasticity of the resin luting cement specimens in our study. Although there is increase in the modulus of elasticity values of resin luting cement, further study at micro level is required in order to assess the changes at molecular level.

Within the limitations of the study, the following conclusions were drawn:

1. After exposure to fractional irradiation for 4 weeks, in the zinc phosphate luting cement (Group-A), showed increase in modulus of elasticity of the test specimens.
2. Among glass ionomer luting cement (Group-B), there was decrease modulus of elasticity due to fractional irradiation.
3. The resin luting cement (Group-C) showed slight increase in modulus of elasticity. Among all the groups, the resin luting cement (Group-C), showed a slight increase in modulus of elasticity when compared to zinc phosphate (Group-A) and glass ionomer (Group-B) luting cement groups after fractional irradiation.

## References

1. Attar N, Tam L E, McComb D, Mechanical and physical properties of contemporary dental luting agents, *J Prosthet Dent* 2003;89:127-34
2. Diaz-Arnold AM, Vargas MA, Haselton DR. Current status of luting agents for fixed prosthodontics. *J Prosthet Dent* 1999;81:135-41
3. Anusavice KJ, Hojjatie B. Tensile stress in glass-ceramic crowns: effect of flaws and cement voids, *Int J Prosthodont* 1992;5:351-8
4. Jemal A, Bray F, Center MM, Ferlay J, Ward E, Forman D. Global cancer statistics. *CA: a cancer journal for clinicians*. 2011 Mar-Apr;61(2):69-90.
5. Jemal A, Murray T, Ward E, Samuels A, Tiwari RC, Ghafoor A, et al. Cancer statistics, 2005. *CA: A cancer journal for clinicians*. 2005 Jan-Feb;55(1):10-30
6. Yesilyurt C, Bulucu B, Sezen O, Bulut G and Celik D, Bond strengths of two conventional glass-ionomer cements to irradiated and non-irradiated dentin *Dental Materials Journal*; 2010;27(5): 695–701
7. Soares CJ, Roscoe MG, Castro CG, Santana FR, Raposo LHA, Quagliatto PS, Novais VR. Effect of gamma irradiation and restorative material on the biomechanical behaviour of root filled premolars. *Int Endod J*. 2011;44(11): 1047-54.
8. Galetti R, Santos-Silva AR, Antunes ANG, Alves FA, Lopes MA, Goes MF. Radiotherapy does not impair dentin adhesive properties in head and neck cancer patients. *Clin Oral Invest*. 2014; 18(7): 1771-8.
9. Kielbassa A M, Wrbas K-Th, Schilte-Monting J, Hellwig E. Correlation of transversal microradiography and microhardness on in situ-induced demineralization in irradiated and nonirradiated human dental enamel. *Archives of Oral Biology* 44 (1999) 243-251
10. Novais V R, Simamoto Jr P C., Rodrigues R B, Roscoe M G, Valdivia A D C M, Soares C J, Effect of irradiation on the mechanical behavior of restorative materials, *Rev Odontol Bras Central* 2015;24(68): 44-8.
11. Kenneth J. Anusavice. *Phillips science of Dental Materials*. 12th, Chapt 14, Elsevier .Pg No.311, Table 14-2
12. Cheung DT, Perelman N, Tong D, Nimmi ME. The effect of  $\gamma$ -irradiation on collagen molecules, isolated  $\alpha$ -chains and cross linked native fibers. *J Biomed Mater Res* 1990; 24: 581-589.
13. Brandeburski SBN, Della Bona A. Effect of ionizing radiation on properties of restorative materials. *Dent Mater* (2017)
14. Cruz A, Sinhoretto M, Ambrosano G, Rastelli A, Bagnato V, Bóscolo F. Effect of therapeutic dose X rays on mechanical and chemical properties of esthetic dental materials. *MaterRes* 2008;11:313–8.
15. Hegde M N , Hegde N D , Kumari S N , Sanjeev G, Priya. Effect of Ionising Radiation on Micro Hardness Property of Restorative Materials. March 2016, *NUJH*; 6(1):58-61
16. White SN, Yub Z. Compressive and diametral tensile strengths of current adhesive luting agents. *J Prosthet D*. June 1993;69:568-72

17. Li ZC, White SN. Mechanical properties of dental luting cements. *J Prosthet Dent* 1999;81:597-609
18. Qing P, Huang S, Gao SS, Qian LM, Yu HY. Effect of gamma irradiation on the wear behaviour of human tooth enamel. *Scientific Report*. June 2015:1-9
19. Bodrumlu E H, Bodrumlu E, Avşar A, Meydan A D, Effect of radiotherapy on the sealing ability of temporary filling materials, *European Journal of General Dentistry* 2015, 4 (1); 8-11
20. Kielbassa A M, Wrbas K-Th, Schilte-Monting J, Hellwig E. Correlation of transversal microradiography and microhardness on in situ-induced demineralization in irradiated and nonirradiated human dental enamel. *Archives of Oral Biology* 44 (1999) 243-251