ORIGINAL ARTICLE

IMPACT OF RESTORATIVE MATERIAL ON FRACTURE STRENGTH OF ROOT CANAL TREATED TEETH: AN IN VITRO STUDY

Syeda Rida Hasan, Maham Muneeb Lone, Aushna Khushbakht Rana, Yawar Ali Abidi
Operative Dentistry Department, Jinnah Sindh Medical University, Karachi-Pakistan

Background: There are several materials available in the market for the core buildup of endodontically treated teeth. The purpose of our study is to evaluate the fracture resistance of endodontically treated teeth restored with composite resin, amalgam and glass ionomer cement as core buildup materials. **Methods:** Forty-eight sound-extracted mandibular premolar teeth were randomly divided into 4 groups of 12 teeth each. The first group served as a control and consisted of intact sound teeth. In all of the remaining teeth, root canal treatment was performed first. In Group II composite resin was used as the core build-up material Group III amalgam and Group IV GIC. Teeth were then subjected to fracture using a universal testing machine**. Results:** One Way ANOVA test was performed to study the differences in the data of the four groups. The mean forces required for fracture were 1050 N for control teeth, 738 N for composite, 872 N for amalgam and 567 N for GIC. The variation is of statistical significance as depicted by a *p*-value of 0.003**. Conclusion:** The highest strength was shown by intact sound teeth. Teeth restored with composite resin and amalgam had similar strengths and those with GIC had significantly lower resistance to fracture.

Keywords: Fracture resistance; Endodontically treated teeth; Composite; Amalgam; Glass ionomer cement

Citation: Hasan SR, Lone MM, Rana AK, Abidi YA. Impact of restorative material on fracture strength of root canal treated teeth: An in vitro study. J Ayub Med Coll Abbottabad 2023;35(4):593–8.

DOI: 10.55519/JAMC-04-11949

INTRODUCTION

Root canal treatment is performed to eradicate infection and retain the tooth in a state that can withstand occlusal loads.[1] Endodontically treated teeth (ETT) have an increased susceptibility to fracture and can be extracted for reasons like vertical tooth fracture, recurrent caries or persistent periodontal disease.[1,2] Dietschi *et al* stated that the reason for this increased susceptibility to fracture is a consequence of the loss of important dental structures like marginal ridges, cusps and the pulp chamber roof.[3] The main variables that influence the fracture strength of ETT are the amount of tooth structure lost, the intact ridges remaining and the restorative material that is used to build up the tooth.[3] The desirable characteristics of a material that is used to restore ETT are that it should be able to replicate the natural tooth in terms of appearance and anatomical details, should be able to assist in function and withstand occlusal loads; should be able to prevent bacterial penetration through microleakage, and help maintain a healthy periodontium.[4] Hence, there is a never-ending quest to find the ideal restorative material.[4]

There are a number of materials and techniques that are being implemented for the restoration of teeth treated endodontically, including direct amalgam and composite restoration, indirect cast restorations and complete coverage crowns.[5] Resin-based materials have the advantage of better aesthetics and a micromechanical bond to the tooth structure.[5] For posterior teeth, amalgam is still popular due to its strength and ability to withstand high masticatory load.[6] The main liabilities of resin-modified glass ionomer are the greater percentage of shrinkage on polymerization as compared to conventional glass ionomer cement, and lower rigidity than that of composite.[7] Glass ionomer cement (GIC) has the unique property of forming a chemical bond with the tooth structure though it must be sticky to do so and must be properly packed down the canal orifices which is a difficult ordeal considering the stickiness.[8]

In our setup, the most commonly used materials for restoring ETT are composite resin, amalgam and GIC. Although there is data available comparing other material.[1,3,4,6,7,9–11] To our knowledge, no study has directly compared the fracture resistance of these materials. More data is needed in this area to aid clinicians in making better decisions for their patients. The objective of this study is to evaluate the fracture strength of root canal-treated mandibular premolars restored with light cure composite, amalgam and conventional GIC. As these are the materials that are being used most commonly by dentists in Pakistan for the restoration of endodontically treated teeth, the outcome of this study will aid clinicians in making better choices.

MATERIAL AND METHODS

It is an in vitro experimental study, conducted in the Operative Dentistry department of Sindh Institute of Oral Health Sciences, Karachi.

After setting the confidence level at 95%, power at 80 and using the mean and standard deviation values from the results of a similar study conducted by Hshad ME in 2017,[4] which were 2156.79±628.04 for Group I and 1445.35±506.18 for Group II, we got a sample size of 11 for each group. We inflated the sample size by 10% to cater for processing errors and the study was carried out on a total of 48 teeth, 12 for each group.

After exemption from the Institutional Review Board was taken, forty-eight human mandibular premolar single-rooted teeth, with similar dimensions (buccolingual: 7.0±0.8 mm; mesiodistal: 5.0±0.5 mm) extracted for reasons like periodontal condition or orthodontic treatment were used. Extracted single-rooted permanent mandibular molars were included. Teeth with fractured roots, teeth with blocked or calcified canals, endodontically treated teeth, teeth with immature apex or showing signs of resorption and teeth with carious lesions were excluded from the study. The teeth were immersed in 5% sodium hypochlorite for one hour to clean them of debris and soft tissue remnants immediately after extraction and then kept in saline solution for 24 hours. A simple randomization technique was used to allocate the teeth to 4 groups.

Group I (Control)

Group I consisted of intact completely healthy sound teeth without any caries or restorative treatment. This group served as control. In all of the remaining teeth, root canal treatment was performed first. Diamond burs (Mani Inc., Tochigi, Japan) were used for access opening and pulp tissue was removed. No. #15 K-files (Kendo, VDW, Munich, Germany) were used to establish the working length of each tooth and the apex was prepared to a Master Apical Size of 35. Taper was prepared with the step-back technique using three consecutive K-files #40, #45, and #50 (Kendo). During the procedure, 2 mL of 5.25% sodium hypochlorite was used for irrigating the canals after each file was used. After canal preparation was completed absorbent paper points (META BIOMED Co, Ltd, Chungbuk, Korea) were used for drying the canals which were then obturated with gutta-percha (GP; META BIOMED Co, Ltd) and Sealapex Root Canal Sealer (Kerr Dental) using a cold lateral condensation technique. A heated plugger was used to remove the excess GP from the chamber and 1mm into the canal orifices. The orifices were then covered with resin modified glass ionomer cement (Vitrebond™ Light Cure Glass Ionomer Liner/Base) 1.5 mm coronal to the cementoenamel junction (CEJ). Completion of these marked successful filling of the root canals after which standard MOD cavities were prepared. The widths of the remaining lingual and buccal walls were standardized to 2.5±0.3 mm, and the height from base of the central fissure to the GP was standardized to 3 mm. The height of the axial walls from the proximal sides was approximately 1.5 mm. The teeth were randomly divided into three experimental groups once MOD preparations were prepared as per the specifications mentioned.

Group II (Composite Resin CR)

3M™ Filtek™ Z250 Universal Restorative was used. The cavities were washed and dried with a triple syringe. 3M™ Scotchbond™ etchant was applied to the tooth surface for 15 seconds. Then the tooth was rinsed of excess water by cotton pellets, leaving the tooth moist. Two coats of 3M Single Bond adhesive was applied, using a completely saturated applicator, to enamel and dentin. The tooth was dried gently for 2-4 seconds and then light-cured for 20 seconds. 3M Filtek Z250 restorative was placed in increments less than 2 mm. Each increment was light-cured for 20 seconds using an LED curing light

Group III Amalgam

Ardent future non-gamma 2, 44.5% silver amalgam alloy was used which is available in self-activating capsules. Amalgam was condensed into the preparations and carved confluent with the cavosurface margins.

Group IV GIC

Gc Gold Label 1 Radiopaque Glass Ionomer Luting Cement was dispensed in a powder/ liquid ratio of 2.7/1.0g (1 drop of liquid to 1 scoop of powder levelled). The powder and liquid were mixed for a total of 30 seconds. The material was then packed into the cavity and finished. Finishing burs, polishing tips and abrasive discs were used to finish the restoration once it is completed.

After that, all the specimens, both experimental and control groups, were mounted into auto-cure poly methyl methacrylate resin approximately 1.5 mm below the cementoenamel junction with a cylinder metal mould (20 mm width, 30-mm length). Care was taken to keep the long axis of the mould parallel to that of the teeth all along these procedures. Once the mounting was done, the samples were subjected to fracture using a universal testing machine (No. 3345J7324, Instron, Norwood, MA, US). A modified stainless-steel ball (6 mm in diameter) was used to apply a compressive force. It was kept parallel to the long axis of the tooth and centred over it until the ball contacted the internal surface of buccal functional cusps and a small part of the restoration. Compressive loading of teeth was performed at a crosshead speed of 0.5 mm/min. The mean loads required to fracture the samples were recorded in Newton (N).

The analysis was done with SPSS 26. Data was further combined and illustrated using descriptive data of the raw and compiled data. Data normality was tested using Kolmogorov-Smirnov and Shapiro-Wilk analysis. As the data was normal, a parametric One-Way ANOVA test was performed to study the differences in the data of the four groups. The statistical significance value was kept at p=0.05.

RESULTS

Graph 1 shows the variation and data dispersion among the data range of the different groups. Table-1 gives a snapshot of the data and presents the minimum and maximum values, mean and standard deviation at fractures. The sig value of 0.003 is less than 0.05 (95% level), showing a significant difference between the fracture strength of the four groups. The highest mean values are that of the amalgam group, the mean values for composite are slightly lower than those of amalgam, while the mean load value for GIC was significantly lower. This variation is statistically significant, as shown by the sig value in the ANOVA table. Table-2 shows the results of post hoc analysis which shows that Control and GIC are the only groups that have a significant difference having a sig value of 0.002.

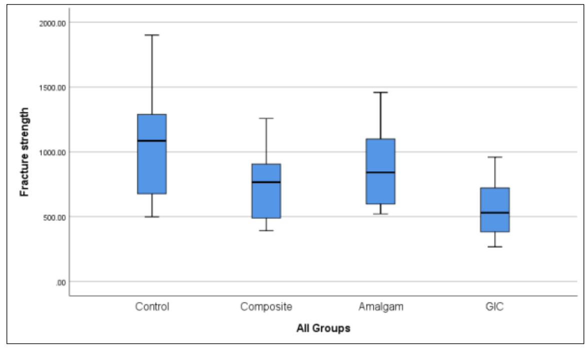

Figure-1: Data Dispersion among data range

Table 1: Forces at the point of fractures in the different groups

Descriptive Statistics						
	N	**Minimum**	**Maximum**	**Mean**	**Std. deviation**	***p*-value***
"Group I (Control)"	12	498.90	1901.00	1062.53	426.05	0.003
"Group Ii (Composite)"	12	390.80	1257.40	737.82	275.16	
"Group Iii (Amalgam)"	12	520.60	1458.80	871.89	300.48	
Group Iv (GIC)	12	266.00	958.80	566.75	227.46	
Valid N (listwise)	12					
*ANOVA was used to check differences in between groups						
**p*-value less than 0.05 was considered significant						

Table 2: Results of post hoc analysis

Dependent Variable: Fracture strength				
(I) All Groups	**(J) All Groups**	**Mean Difference (I-J)**	**Std. Error**	**Sig.***
Control	Composite	324.71	128.98	.071
	Amalgam	190.63	128.98	.459
	GIC	495.78*	128.98	.002
Composite	Control	-324.71	128.98	.071
	Amalgam	-134.08	128.98	.727
	GIC	171.07	128.98	.551
Amalgam	Control	-190.63333	128.97931	.459
	Composite	134.07500	128.97931	.727
	GIC	305.14167	128.97931	.099
GIC	Control	-495.77500*	128.97931	.002
	Composite	-171.06667	128.97931	.551
	Amalgam	-305.14167	128.97931	.099
*Post Hoc Analysis was applied to study mean difference amongst the groups				
*The mean difference is significant at the 0.05 level.				

DISCUSSION

Clinicians still face difficulties when attempting to restore badly damaged teeth that were previously extracted, due to patient desire. Restoration failure is the most common reason for unsuccessful endodontic treatment outcomes. A good outcome from root canal therapy depends heavily on the ultimate restoration, as failure to do so might result in tooth extraction. Endodontic obturation with gutta-percha and an insoluble root canal sealer is widely regarded as the gold standard of root canal fillings. There is substantial debate over whether or not these materials may effectively strengthen an endodontically treated root.[12] A systemic review was conducted by Uzunoglu-Özyürek E in 2018 on the effect of root canal sealers on the fracture resistance of root canal-treated teeth which concluded that root canal sealers combined with root canal obturation material increased the resistance of endodontically treated teeth to fracture.[13]

Both traditional and intra-radicular reinforcement techniques are used for teeth that have been treated endodontically. A study conducted in 2020 compared the fracture strength of endodontically treated teeth restored with different fiber post systems and found that RelyX Fiber Post and Filtek Bulk Fill Posterior demonstrated the greatest resistance to fracture.[14] Mena-Álvarez J *et al* evaluated the fracture resistance of root-treated premolars restored with fiber-reinforced composite and elastic post. Their results showed that the use of elastic post increased the resistance to fracture as compared to fibre-reinforced composite post or composite resin core alone.[15] Haralur SB compared the fracture resistance of endodontically treated teeth restored with polyether ether ketone (PEEK) post, fibre-reinforced composite post and polymer infiltrated ceramic post and found that the PEEK endodontic post displayed the highest resistance to fracture.[16] However, it is well documented in the literature that instead of strengthening the tooth, preparation of post space may weaken the tooth and may predispose it to vertical root fracture.[17,18] Hence the recommendation is to use a post only when the coronal structure is insufficient to support a coronal restoration and reinforcement is necessary.[19] Therefore instead of post a strong placed restorative material is more important in restoring strength to the tooth.

Several studies have been conducted that evaluate the strength of various core build-up materials. A study conducted in India evaluated the fracture strength of endodontically treated premolars restored using composite resin, GIC and alkasite cement. Similar to the results of our study, they also concluded that composite resin performed significantly better and should be used as a material of choice for core build-up, and alkasite cement can be used in selected cases where ease of manipulation is required.[20] Guo YB *et al* in their study on the fracture resistance of root-treated teeth with cervical defects reported that teeth restored with direct composite resin after endodontic treatment regained their strength to 72% of the intact untreated teeth.[21] While our study evaluated the strength of only bulk flow composite, a study compared the fracture strength of teeth restored using conventional composite resin, conventional composite resin with a glass fibre post, bulk flow flowable and bulk flow restorative composites and ceramic inlay. The results showed that all the groups exhibited fracture resistance similar to that of sound teeth, however, teeth restored with conventional composite resin had the least strength.[22] Another study compared the fracture resistance of coltosol, glass ionomer cement, modified glass ionomer cement, and composite resin. This study again reported similar outcomes to that of our study and concluded that teeth restored using composite resin and modified GIC had fracture resistance similar to that of intact teeth and those restored with coltosol and GIC showed significantly lower fracture resistance similar to that of unrestored teeth.[23] Göktürk H *et al* conducted a study in which they evaluated the fracture resistance of endodontically treated premolars restored using direct composite resin, direct composite resin pre-impregnated with glass fibres and ceramic inlay restoration. They found that fracture resistance of all the restored teeth was lower than that of intact teeth, however, there was no significant difference in the fracture resistance of teeth restored using different materials.[24] Daher R *et al* compared the fracture resistance of endodontically treated mandibular molars with mesio-occluso-distal (MOD) cavities reinforced with direct composite resin, direct composite resin with glass fibre-reinforced strip wrapped around the buccal and lingual walls, indirect CAD/CAM composite inlay and indirect CAD/CAM composite onlay. The results did not show any statistically significant difference in the fracture resistance of the groups however the inlay and onlay group exhibited the most catastrophic fractures, followed by the group with direct composite resin and the glass fibre reinforced group showed the least percentage of catastrophic fractures.[25] A systemic review of in vitro studies conducted by Zarow, M *et al* concluded that composite resin core build-up materials with higher filler content showed greater fracture resistance as compared to conventional composites.[26] However none of the studies compared the strength of composite to amalgam, which as shown by the results of our study still performs better than light cure composite in terms of strength.

Endodontic access cavity design also has a significant effect on the fracture resistance of endodontically treated teeth. In our study, we used MOD cavities because this is a very extensive cavity leading to a loss in strength of the intact tooth so that we can see how much of the original strength can the coronal material restore. Literature reports that the number of residual walls has a great influence on the fracture strength of endodontically treated teeth and loss of both mesial and distal marginal ridges significantly decreased fracture resistance.[27] Balkaya, H *et al* evaluated the effect of access cavity design and temporary filling material on the fracture resistance and concluded that temporary filling material had no effect on fracture resistance, however, access cavity design did influence fracture strength of the teeth.[28] Sabeti M *et al* in their study also concluded that increasing the taper of root canal preparation and more extensive access cavities also decreased fracture resistance.[29] Saberi, EA *et al* also concluded in their article that in teeth without extensive caries conservative access cavity design is a very effective means of enhancing fracture strength of endodontically treated teeth.[30] In our study all the teeth had standardized access cavity design so that the effects of access cavity on the fracture strength can be minimized.

Our results show that teeth restored with composite resin and amalgam resin have significantly more fracture resistance compared to teeth restored with glass ionomer cement. The strength of our study is it is a lab experiment in which confounding variables have been controlled minimizing bias. Also commonly used core build-up materials in our society have been investigated. One limitation of our study is that it is an in vitro lab experiment which cannot exactly simulate the situation inside the oral cavity where the teeth are subjected to occlusal loading, which results in repeated cycles of stress which can also lead to fatigue failure over time. Another limitation of our study is that it has not included the different kinds of composite resin materials that are available in the market and have different strengths. The lower strength of GIC can be attributed to the porosities in the material and the inherent solubility of the cement. More work is needed in this area to compile more extensive data regarding the different material subtypes.

CONCLUSION

Within the limitations of this study, it can be concluded that composite resin and amalgam perform far better as core build materials than glass ionomer cement. Both of these can be used in non-esthetic areas, however, composite resin will be the material of choice in anterior and aesthetic zones.

AUTHORS' CONTRIBUTION

SRH: Conceptualization, methodology, data collection, write-up, review and editing. MML: Visualization, investigation. AKR: Software, formal analysis. YAA: Supervision.

REFERENCES

1. Uzunoglu-Özyürek E, Küçükkaya Eren S, Eraslan O, Belli S. Critical evaluation of fracture strength testing for endodontically treated teeth: a finite element analysis study. Restor Dent Endod 2019;44(2):1124644.
2. Ilgenstein I, Zitzmann NU, Buhler J, Wegehaupt FJ, Attin T, Weiger R, *et al*. Influence of proximal box elevation on the marginal quality and fracture behavior of root-filled molars restored with CAD/CAM ceramic or composite onlays. Clin Oral Investig 2015;19(5):1021–8.
3. Forster A, Sáry T, Braunitzer G, Fráter M. In vitro fracture resistance of endodontically treated premolar teeth restored with a direct layered fiber-reinforced composite post and core. J Adhes Sci Technol 2017;31(13):1454–66.
4. Hshad ME, Dalkilic EE, Ozturk GC, Dogruer I, Koray F. Influence of Different Restoration Techniques on Fracture Resistance of Root-filled Teeth: In Vitro Investigation. Oper Dent 2018;43(2):162–9.
5. Ozsevik AS, Yildirim C, Aydin U, Culha E, Surmelioglu D. Effect of fibre-reinforced composite on the fracture resistance of endodontically treated teeth. Aust Endod J 2016;42(2):82–7.
6. Lin G, Ghani N, Noorani T, Ismail N. Fracture resistance of the permanent restorations for endodontically treated premolars. Eur J Gen Dent 2018;7(3):56–60.
7. Subash D, Shoba K, Aman S, Bharkavi SKI, Nimmi V, Abhilash R. Fracture Resistance of Endodontically Treated Teeth Restored with Biodentine, Resin Modified GIC and Hybrid Composite Resin as a Core Material. J Clin Diagn Res 2017;11(9):ZC68–70.
8. Eliyas S, Jalili J, Martin N. Restoration of the root canal treated tooth. Br Dent J 2015;218(2):53.
9. Abumelha AS, Alqahtani AMA, Hassan SAMB, Ain TS. Restorations and survivability of endodontically treated teeth. Int J Med Dent 2018;8(2):55–60.
10. Aslan T, Sagsen B, Er O, Ustun Y, Cinar F. Evaluation of fracture resistance in root canal-treated teeth restored using different techniques. Niger J Clin Pract 2018;21(6):795–800.
11. Chan T, Kucukkaya Eren S, Wong R, Parashos P. In vitro fracture strength and patterns in root-filled teeth restored with different base materials. Aust Dent J 2018;63(1):99–108.
12. Burke F. Tooth fracture in vivo and in vitro. J Dent 1992;20(3):131–9.
13. Uzunoglu-Özyürek E, Küçükkaya Eren S, Karahan S. Effect of root canal sealers on the fracture resistance of endodontically treated teeth: a systematic review of in vitro studies. Clin Oral Investig 2018;22(7):2475–85.
14. Özyürek T, Topkara C, Koçak İ, Yılmaz K, Gündoğar M, Uslu G. Fracture strength of endodontically treated teeth restored with different fiber post and core systems. Odontology 2020;108(4):588–95.
15. Mena-Álvarez J, Agustín-Panadero R, Zubizarreta-Macho A. Effect of Fiber-Reinforced Composite and Elastic Post on the Fracture Resistance of Premolars with Root Canal Treatment—An In Vitro Pilot Study. Appl Sci 2020;10(21):7616.
16. Haralur SB. Fracture resistance of endodontically treated teeth restored with various esthetic posts. Technol Health Care 2021;29(2):243–52.
17. Fuss Z, Lustig J, Katz A, Tamse A. An evaluation of endodontically treated vertical root fractured teeth: impact of operative procedures. J Endod 2001;27(1):46–8.
18. Reddy TVK, Chellapandian K, Priyadharshini V, Venkatesh KV. Recent trends in vertical root fracture: A review. Int J Health Sci 2022(II):11467–75.
19. Iqbal N, Farooq S. Rehabilitation of endodontically treated tooth with cast post and core: A case study. Int J Appl Dent Sci 2020;6(3):84–6.
20. Sharma A, Das S, Thomas MS, Ginjupalli K. Evaluation of fracture resistance of endodontically treated premolars restored by alkasite cement compared to various core build-up materials. Saudi Endod J 2019;9(3):205.
21. Guo YB, Bai W, Liang YH. Fracture resistance of endodontically treated teeth with cervical defects using different restorative treatments. J Dent Sci 2022;17(2):842–7.
22. Mergulhão V, De Mendonça L, De Albuquerque M, Braz R. Fracture resistance of endodontically treated maxillary premolars restored with different methods. Oper Dent 2019;44(1):E1–11.
23. Maeda W, Nascimento WM, Coelho MS, de Luca Campos D, Drumond JP, de Jesus Soares A, *et al*. Evaluation of Fracture Resistance of Endodontically Treated Maxillary Premolars Restored with Different Restorative Materials-An In Vitro Study. Res Soc Dev 2021;10(7):e5110716150.

24. Göktürk H, Karaarslan EŞ, Tekin E, Hologlu B, Sarıkaya I. The effect of the different restorations on fracture resistance of root-filled premolars. BMC Oral Health 2018;18(1):1–8.
25. Daher R, Ardu S, Di Bella E, Rocca GT, Feilzer AJ, Krejci I. Fracture strength of non-invasively reinforced MOD cavities on endodontically treated teeth. Odontology 2021;109(2):368–75.
26. Zarow M, Dominiak M, Szczeklik K, Hardan L, Bourgi R, Cuevas-Suárez CE, *et al*. Effect of composite core materials on fracture resistance of endodontically treated teeth: A systematic review and meta-analysis of in vitro studies. Polymers 2021;13(14):2251.
27. Corsentino G, Pedullà E, Castelli L, Liguori M, Spicciarelli V, Martignoni M, *et al*. Influence of access cavity preparation and remaining tooth substance on fracture strength of endodontically treated teeth. J Endod 2018;44(9):1416–21.
28. Balkaya H, Topçuoğlu HS, Demirbuga S. The effect of different cavity designs and temporary filling materials on the fracture resistance of upper premolars. J Endod 2019;45(5):628–33.
29. Sabeti M, Kazem M, Dianat O, Bahrololumi N, Beglou A, Rahimipour K, *et al*. Impact of access cavity design and root canal taper on fracture resistance of endodontically treated teeth: an ex vivo investigation. J Endod 2018;44(9):1402–6.
30. Saberi EA, Pirhaji A, Zabetiyan F. Effects of endodontic access cavity design and thermocycling on fracture strength of endodontically treated teeth. Clin Cosmet Investig Dent 2020;12:149–56.

Submitted: April 2, 2023	*Revised: June 26, 2023*	*Accepted: August 8, 2023*

Address for Correspondence:

Syeda Rida Hasan, R-74, Pilibhit Chs, Sector 18-A, Gulzar E Hijri Scheme 33, Karachi-Pakistan
Cell: +92 312 506 2833
Email: ridahasan4@gmail.com