



PROJECT COMPLETION REPORT

1. **Project Number** : 7012
2. **Title of the Project** : Development and biocompatibility studies on organically modified ceramics for medical applications
3. **Funding Agency Name** : DST,India
4. **Project Reference Number provided by the Funding Agency:** DST No:SR/FTP/LS-295/2000
5. **Principal Investigator (Name & Address) :** Dr.Lizymol P.P. ,Scientific Assistant, Division of Dental Materials, BMTW,SCTIMST
6. **Co-Investigators (Name & Address):** NIL
7. **Implementing Institution** : SCTIMST
8. **Collaborating Institutions** : NIL
9. **Date of Commencement** : 26.07.2001
10. **Duration** : 3 years
11. **Date of Completion** : 25.07.2004
12. **Objectives as approved :** At present amalgam is used for posterior filling in dentistry due to its exceptional strength. However amalgam has the drawback of toxicity due to the presence of mercury. So we are trying to develop organically modified ceramics to replace amalgam in medical applications. Currently all dental composite materials used in India are imported leading to huge loss of foreign exchange. So the indigenous development is expected to contribute to country's economy substantially
13. **Deviation made from original objectives if any, while implementing the project and reasons thereof :** NIL
14. **Field/Experimental work giving full details of summary of methods adopted, data collected supported by necessary tables, charts, diagrams and photographs :**

Methodology : New inorganic organic hybrid materials, which are organically modified ceramic resin containing alkoxides or mixtures of alkoxides of silicone, aluminum, calcium and titanium with various polymeric methacrylate groups were synthesized by the preferential hydrolysis and post condensation of organo silanes. The various resins were characterized using Abbe Refractometer and FTIR Spectrophotometer. The refractive indexes of the various resins are shown in Table 1. Selected resins which are found soluble in organic solvents were characterized using high pressure liquid chromatography. (Waters HPLC system, C18 column, mobile phase methanol, flow rate 1ml/min.) Thermal stability of a few of the developed resins were characterized using thermogravimetry methods (TA Instruments, heating rate, nitrogen atmosphere, 10°C/min) and compared with conventional organic resins. (Table 2) Effects of diluent content (triethylene glycol dimethacrylate (TEGDMA)) on various properties of dental composites prepared using these novel resins were studied. Properties (diametral tensile strength (DTS), flexural strength (FS), flexural modulus (FM), Vickers hardness number (VHN), water sorption (WS) and solubility) are given in Table 3. Effects of various inorganic materials present in the inorganic organic hybrid resins on the properties of cured dental composites were studied. (Table 4). Preliminary studies were carried out to evaluate adhesive strength of dentine bonding agent prepared using the novel resin.

Resin synthesized	Refractive index
Ormo R1	1.4484
Ormo R1-Si	1.4662
Ormo R1-Ca	1.43
Ormo R1-Al	1.4674
Ormo R1-Ti	1.472
Ormo R17	1.4822
Ormo R20	1.4756
Ormo R21	1.4794
Ormo R23	1.4864

Table 1. Refractive index of resins synthesized

Resin used	Inorganic content	T0 °C	T50 °C	% residue at 600°C
Bis GMA	Nil	336	422	12
UTMA	Nil	150	321	2.85
Ormo R ₆	(precursor)	369	550	48.5
Ormo R ₁₅	Al(OH) ₃	353	520	47

Ormo R ₁₇	Ca(OH) ₂ + silica	392	435	33
Ormo R ₂₀	Tetra isopropyl orthotitanate	313.8	589	49.7
Ormo R ₂₁	Silica	378	551	48.39

Table 2. Comparison of T₀ and T₅₀ values of different oligomers studied

15. Detailed analysis of results :

Property evaluated ↓	Material Tested		
	Ormo R17 (70)/ TEGDMA(30)	Ormo R17 (60)/ TEGDMA 40	Ormo R17 (50)/ TEGDMA 50
Depth of cure	3.03±0.03	3.1±0.04	3.1±0.06
DTS(MPa)	26.4±1.8	34.22 ± 1.6	35.63 ±1.56
FS (MPa)	41.29 ± 1.8	37.27 ± 3.08	59.63± 9.54
FM(GPa)	7.06 ± 0.78	8.3 ± 0.62	8.7 ± 1.9
VHN (Kg/mm ²)	81 ± 1.29	85.2 ± 1.02	91.6 ± 2.14
WS (µg/mm ³)	31.01	20.91	22.26
Solubility(µg/mm ³)	8.4	4.15	7.09

Table 3. Effects of diluent content on various properties of dental composites prepared using these novel resins

Sample code	Inorganic material incorporated	DTS (MPa)	FS (MPa)	FM (MPa)	VHN (Kg/mm ²)
Ormo 48	Ca(OH) ₂ + silica	35.68±1.6	59.63 ± 9.54	8712 ± 1862	91.6 ± 2.14
Ormo 60	Silica	43.93 ± 3.9	78.5 ± 8.13	7772 ± 1911	64.9 ± 3.21
Ormo 62	Tetra isopropyl ortho titanate	38.93±1.29	75.94 ± 7.17	9280 ± 925	49.2 ± 0.8
Ormo 44	Silica + Al(OH) ₃	23.9 ± 2.02	17.43 ± 2.59	5674 ± 1025	49.1 ± 1.60

Table 4. Effects of inorganic content present in organically modified ceramics resins on properties of their composites.

Biocompatibility Studies of Dental Composites.

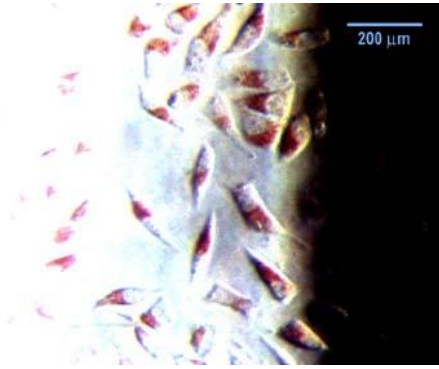
Cytotoxicity Evaluation

Cytotoxicity Evaluation of dental composite was carried out as per ISO 10993-5 (1999) using indirect contact method. Cured dental composite test samples prepared from ormoresin R₁₀ (ormoR₁₀C), Ormoresin R₁₇ (ormoR₁₇C) and Ormoresin R₂₃ (ormoR₂₃C) were evaluated. Ultra high molecular weight polyethylene was used as the negative control and copper was used as the positive control. Test samples, negative controls and positive controls in triplicate were placed on an agar overlaid over sub confluent monolayer of L-929 mouse fibroblast cells. L-929 is an established and well characterized mammalian cellline that has demonstrated reproducible results. Cell culture was examined microscopically for cellular response around test samples after incubation of cells with test samples at 37 ± 2°C for 24 ± 1h. Cellular responses were scored as 0, 1, 2 and 3 according to non cytotoxic, mildly cytotoxic, moderately cytotoxic and severely cytotoxic. Results of qualitative evaluation were given in Table 17. Test samples ormo R₁₀C and ormoR₁₇C are noncytotoxic and ormoR₂₃C was mildly cytotoxic to fibroblast cells. Negative control gave noncytotoxic response and positive control gave severely cytotoxic response.

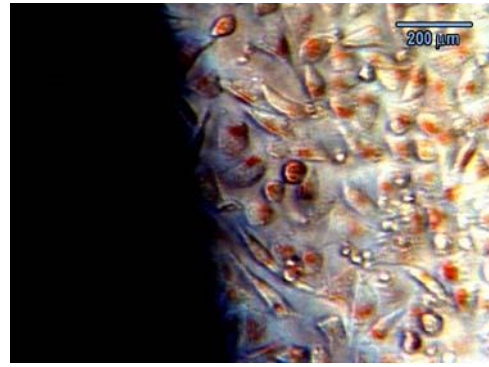
Sl.No.	Sample	Cytotoxicity scale	Interpretation
1	Negative Control	0	Noncytotoxic
2	Positive Control	3	Severely Cytotoxic
3	Ormo R ₁₀ C	0	Noncytotoxic
4	OrmoR ₁₇ C	0	Noncytotoxic
5	OrmoR ₂₃ C	1	Mildly cytotoxic

Table Qualitative evaluation- Cytotoxicity

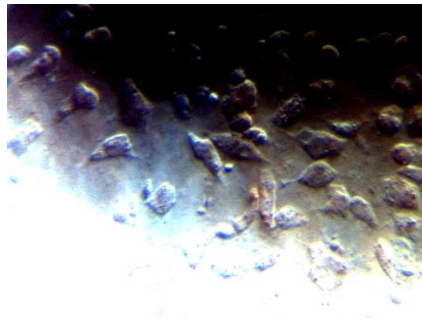
As all the ingredients of dentine bonding agent are included in dental composites which passed cytotoxicity, it is not necessary to evaluate the cytotoxic character of dentine bonding agent.



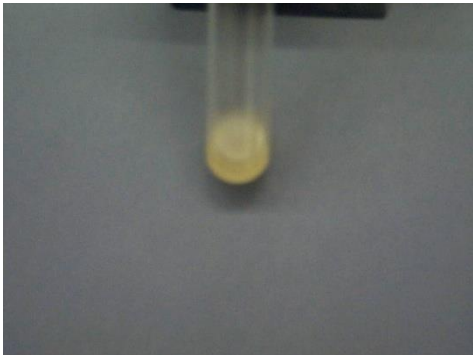
Fibroblast cells around Ormo60 composite



Fibroblast cells around Ormo48 composite



Fibroblast cells around Ormo62 composite



Organically modified ceramics resin and composite

16. **Summary sheet of not more than 2 pages under following heads : (Title, Introduction, Rationale, Objectives, Methodology, Results, Translational Potential)**

Title, Development and biocompatibility studies on organically modified ceramics for medical applications

At present amalgam is used for posterior filling in dentistry due to its exceptional strength. However amalgam has the drawback of toxicity due to the presence of mercury. So we are trying to develop organically modified ceramics to replace amalgam in medical applications. Currently all dental composite materials used in India are imported leading to huge loss of foreign exchange. So the indigenous development is expected to contribute to country's economy substantially

Methodology, Materials

The materials used in this study are 3(methacryloxypropyl-trimethoxy-silane), triethylene glycol dimethacrylate (TEGDMA), and 2,2 bis (4(2 hydroxy-3 methacryloxy-propoxy)phenyl)propane (BisGMA)(Aldrich Chem. Co. Milwaukee) Tetra isopropylorthotitanate and chloropropyl trimethoxy silane(Merck Schuchardt, Germany), Laboratory Rasayan(LR) grade calcium hydroxide, LR grade aluminum hydroxide gel, LR grade sodium hydroxide, AnalyticalRasayan grade hydrochloric acid, and specially dried LR grade diethyl ether (S.D. Fine Chemicals,Mumbai, India)

The dimethacrylate resin, 1,3-bis methacryloxy 2-(trimethoxysilyl propoxy) propane (Ormoresin R2) was synthesized by reacting 1.1 moles of glycerol dimethacrylate (which was synthesized in our lab as reported earlier) with 1 mole of chloropropyl trimethoxysilane in presence of benzyl triethyl ammonium chloride catalyst. The mixture was allowed to react at 50–55°C under constant stirring for 6 h.

Results,

HPLC results showed that the resins are pure. In HPLC of Ormo R₆ the main elutant is at a retention time of 0.991 minute. The other two peaks at retention time 1.881 and 3.631 may be due to presence of inhibitor and unreacted silane both of which are mandatory for composite preparation. In HPLC Ormo R₁₀ the main elutant is at a retention time of 0.988 minute. The other two peaks at retention time 1.842 and 3.634 may be due to presence of inhibitor and unreacted silane. In HPLC Ormo R₁₇ the main elutant is at a retention time of 1.322 minute. The other two peaks at retention time 2.075 and 2.317 may be due to presence of incorporated inorganic contents.

Thermal studies showed (Table 2) that thermal degradation of all the resins started only after 350°C. FTIR spectroscopic evaluation revealed the hydrolysis and post condensation reaction between inorganic and organic constituents result the formation of inorganic organic precursors for the development of dental composite. Pastes for visible light cure dental composite were prepared using the different inorganic organic hybrid resins synthesized. Effects of different metal alkoxides and diluents on the properties of composites were studied. The composites were characterized in terms of diametral tensile strength (DTS) flexural strength (FS) flexural modulus (FM) and Vickers Microhardness number (VHN). Preliminary studies on development of dentine bonding agent (dba) based on ormoresin were started. A shear strength value of 4.01 ± 1.64 MPa was obtained for the dentine bonding agent.

Translational Potential: Non radiopaque dental composite with good mechanical properties suitable for paediatric tooth filling

17. Contributions made towards increasing the state of knowledge in the subject :

Chemical process for synthesis of low shrinkage multifunctional organically modified ceramic resin for medical applications.

(Special highlight in Technology News Focus 2010-03-17 “New findings from P.P.Lizymol and co-authors describe advances in applied polymer science” Journal of Technology March 16, 2010 “New findings from P.P. Lizymol and co-authors describe advances in applied polymer science”

Special highlight in News RX, 2010-05-11 “Studies from P.P.Lizymol and colleagues reveal new findings in Medical Science”s. Science Letter, May 11th, 2010 “Studies from P.P.Lizymol and colleagues reveal new findings on polymer science” Source:)

18. Conclusions summarising the achievements and indication of scope for future work :

Inorganic -organic hybrid materials are found to have good thermal stability compared to conventional organic oligomers. It is already found that incorporation of inorganic element to organic matrix improves the hardness values of composite substantially compared to composite containing purely organic resin. All other properties like CS, DTS, FS, and FM of dental composites prepared using the different inorganic organic hybrid resins are comparable to conventional dental restorative composites. Further studies for the development and characterization of radiopaque material and cytotoxic and toxicological evaluation of dental composite and dentine bonding agent remain to be done.

19. Science and Technology benefits accrued :

a. List of research publications with complete details :

1. Lizymol, P. P*. Studies on new organically modified ceramics based dental restorative resins, Journal of Applied Polymer Science, 2010, 116; 509-517.

(Special highlight in Technology News Focus 2010-03-17 “New findings from P.P.Lizymol and co-authors describe advances in applied polymer science” Journal of Technology March 16, 2010 “New findings from P.P. Lizymol and co-authors describe advances in applied polymer science”

2. Lizymol, P.P*. Studies on shrinkage, depth of cure, and cytotoxic behavior of novel organically modified ceramic based dental restorative resins, Journal of Applied Polymer Science, 2010, 116; 2645-2650,

Special highlight in News RX, 2010-05-11 “Studies from P.P.Lizymol and colleagues reveal new findings in Medical Science”s. Science Letter, May 11th, 2010 “Studies from P.P.Lizymol and colleagues reveal new findings on polymer science” Source:)

3. **Lizymol P.P.*** Thermal studies: a comparison of the thermal properties of different oligomers by thermogravimetric techniques, J Applied Polymer Science 200493: 977-985,
4. **Lizymol P.P.*** Effects of Diluent Concentration upon the Properties of Organically Modified Ceramics Based Composites for Application in Dentistry, J Applied Polymer Science, 2004, 94: 469-473,
5. **Lizymol, P. P.*;** Kalliyana Krishnan, V., Aging Effects of Dental Restorative Materials upon Surface Hardness, Journal of Polymer Materials, 2009, 26; 207-214
6. **Lizymol P.P.*;** Mohanan P.V., Shabareeswaran Kalliyanakrishnan V. Biological evaluation of a new organically modified ceramic based dental restorative resin submitted journal of bioactive and compatible polymers Journal of Applied Polymer Science 2012, 125, 620–629.
7. **Mohanan, PV*, Lizymol P.P.;** Cytogenetic Evaluation of the Physiological Saline Extract of a Newly Developed Dental Material ORM0-48 Toxicology International, 2011, 18; 155
8. **Lizymol P.P.*.** Novel inorganic organic hybrid resins as biomaterials “Recent Advances in Material Science; Series Journal : Composites and Nanocomposites Editor: Dr.A.K.Haghi, Publisher : Apple Academic Press, (Publisher CRC Press) Canada. (Vol. 4). (2013) Chapter: 8 2013/3/1 Pages 89 (Book chapter).
9. **Lizymol P.P.*.** Physical and Mechanical Properties of Visible Light Cure Composites Based on Novel Organically Modified Ceramic Resins Advanced Materials Research Vol. 685 (2013) pp 50-53.

- b. Manpower trained on the project :**
- | | | |
|--|---|-----|
| i. Research Scientists or Research Fellows | : | NIL |
| ii. No. of PhD’s produced | : | NIL |
| iii. Other Technical Personnel trained | : | NIL |
- c. Patents taken, if any** : **1**

Inventors: **Pampadykandathil Philipose Lizymol,** Venkateswaran Kalyanakrishnan A modified ceramic resin for use in dental applications and a process for the preparation thereof, , 219733, 12/06/2003

- d. Products developed, if any** : **Dental composite (non radiopaque)**

20. Abstract: (In 300 words for possible publication in Bulletin)

- a. Background:** The various composites available in the market have limitations such as shrinkage during curing, and monomer release and subsequent allergy reactions.

In order to overcome these limitations of amalgam and composites attempts have been initiated on the development of organically modified ceramics for application in dentistry. Dental composite prepared using the different inorganic organic hybrid resins are expected to have low shrinkage during curing, good mechanical properties, abrasion resistance, suitable elasticity, adhesion to teeth and good toxicological results.

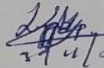
- b. Materials:** New inorganic organic hybrid materials, which are organically modified ceramic resin containing alkoxides or mixtures of alkoxides of silicone, aluminum, calcium and titanium with various polymeric methacrylate groups were synthesized by the preferential hydrolysis and post condensation of organo silanes.
- c. Results:** Inorganic -organic hybrid materials are found to have good thermal stability compared to conventional organic oligomers. It is already found that incorporation of inorganic element to organic matrix improves the hardness values of composite substantially compared to composite containing purely organic resin. All other properties like CS, DTS, FS, and FM of dental composites prepared using the different inorganic organic hybrid resins are comparable to conventional dental restorative composites
- d. Conclusion:** These new hybrid materials consist of nanocrystalline inorganic particles incorporated in an organic matrix. The inorganic particles made by sol-gel technique were modified chemically by bonding to different organic matrices. The resulting materials have the unique properties of the inorganic materials with those of an organic network.

21. Procurement/Usage of Equipment:

a. Details of Equipment:

Sl. No.	Name of Equipment	Make/ Model	Cost (Rs.)	Date of Installation	Utilisation	Remarks regarding maintenance breakdown
1	Micro Vickers Hardness Tester	Model HMV 2, Shimadzu, Japan)	4,58,624/-	27.05.2002	100%	Equipment is in good condition

b. **Suggestions for disposal of equipment(s):**Not Applicable

Dr. Lizymol P.P

24/11/2025
(Name and Signature of PIs with date)

Routing: Signed copy of "Project completion Report" by PI → root@sctimst.ac.in, rpc@sctimst.ac.in