RESEARCH ARTICLE

Improving dimensional stability of dental amalgam by using Nano Zinc Oxide

Abdur Rehman[1], Nimrah Khalil[2], Ahsan Saleem[3], Nadeem Hafeez Khokhar[4], Syed Junaid Mehmood[5], Abdul Frahim Khan[6]

Abstract

Objective: To investigate the dimensional stability of dental amalgam after the incorporation of zinc oxide nano powder

Methods: The experimental study was conducted at the Hamdard University Dental Hospital and the Pakistan Council of Scientific and Industrial Research laboratories, Karachi, from January to June, 2018. Direct precipitation method was used in which analytical grade sodium hydroxide and zinc nitrate hex hydrate were used without any further purification. The sample was randomly divided into two groups. The control group A had 0 wt.% of nano zinc oxide, while the experimental group was further divided into 2 subgroups, with group B containing samples having 3 wt.% and group C 5 wt.% of nano zinc oxide.

Delayed expansion was checked using electron micrometer. Data was analysed using SPSS 22.

Results: Of the 180 samples, there were 90(50%) in control group A, and 45(25%) each in experimental groups B and C. Subgroup B showed significantly more linear expansion than subgroup C. Subgroups B and C achieved their entire linear expansion after 24 hours.

Conclusion: There was improvement in the dimensional stability of dental amalgam after the incorporation of nano particles of zinc oxide.

Keywords: Dental Amalgam, Nano zinc, Nano-materials, Contraction, Expansion, Delayed expansion (JPMA 70: 830; 2020). **https://doi.org/10.5455/JPMA.10690**

Introduction

Regardless of an increased focus on its prevention, dental caries remain an important global public health concern.[1,2] Despite the availability of various dental restorative materials, like glass ionomer cements, composite restorative material etc., dental amalgam is considered one of the most reliable and cost-effective material for almost 150 years.[3] It is a combination of various metallic alloys with a complex structure formed by reaction between mercury and dental alloy, containing predominantly silver, tin and zinc.[4] American National Standards Institute / American Sental Association (ANSI/ADA) specification no 1 requires that amalgam alloy contain predominantly silver and tin. According to International Standards Organisation (ISO) standard 24234, unspecified amount of other elements, for example zinc, copper and gold are allowed in concentration less than silver or tin content.[4]

Despite being one of the most reliable dental restorative materials, the World Health Organization (WHO), the World Dental Federation (FDI) and various other health organisations have encouraged the phasing down the use of dental amalgam because of its high mercury content and subsequent toxicity.[5,6] But, on the other hand, various health organisations and published articles stated that the amount of mercury present within the dental amalgam restoration is not injurious to the medical health of the recipient.[6,7] Therefore, studies on how to reduce the mercury toxicity and to further improve the properties of dental amalgam are still conducted. This is the reason behind the incorporation of micro and nano particles, such as zinc oxide, aluminium oxide, titanium oxide etc.

Zinc oxide, having the richest family of nano structure, is a unique material both in structure and properties.[4] It is present in various morphological form e.g. nanotubes, nano rods, nano spheres etc.[8] Meanwhile its properties are dependent on its structure and morphological state

[1]Department of Science and Dental Material, Hamdard College of Medicine and Dentistry, Hamdard University, Karachi, Pakistan; [2]Science of Dental Material, Dr Ishrat Ul Ebad Khan Institute of Oral Health Sciences, Pakistan; [3]Operative Dentistry, Hamdard College of Medicine and Dentistry, Hamdard University, Karachi, Pakistan; [4]Hamdard College of Medician and Dentistry, Karachi, Pakistan; [5,6]ACRC-Polymer and Plastic Section, PCSIR labs complex, Karachi, Pakistan.
Correspondence: Abdur Rehman. e-mail: abdurrehmanmds@gmail.com

which varies according to its method of manufacturing.[4]

Keeping in mind the diversity related to zinc oxide, the current study was planned to investigate the dimensional stability of dental amalgam after the incorporation of zinc oxide nano powder.

Material and Methods

The experimental study was conducted at the Hamdard University Dental Hospital and the Pakistan Council of Scientific and Industrial Research (PCSIR) laboratories, Karachi, from January to June, 2018. The samples were prepared at the Polymer Department of PCSIR. The sample size was calculated using OpenEpi software version 39, and the mean value used was 1.22 for group A and 1.23 for group B whereas standard deviation of 0.01 was used for both the groups. Confidence interval (CI) and power of 95% and 80% were used respectively.[9] The sample was raised using convenience sampling.

Of all the samples fabricated, those without any visible structural defects, like voids, cracks and porosities, and fulfilling the criteria of ISO 24234:20154 were selected. Samples containing structural defects were excluded.

The sample was randomly divided into two groups. The control group A had 0 wt.% of nano zinc oxide, while the experimental group was further divided into 2 subgroups, with group B containing samples having 3 wt.% and group C 5 wt.% of nano zinc oxide.

For synthesis, direct precipitation method was used in which analytical grade sodium hydroxide (NaOH) and zinc nitrate hex hydrate ($Zn[NO_3]_2.6H_2O$) were used without any further purification. The production unit of zinc oxide nano particle consisted of Erlenmeyer flask, graduated cylinder and a magnetic stirrer. In two separate flasks, NaOH and $Zn[NO_3]_2.6H_2O$ were added in distilled water under constant stirring until complete dissolution of the constituents were achieved. The prepared NaOH solution was slowly added (dripped for 45-60 min) along the walls of Erlenmeyer flasks containing $Zn[NO_3]_2.6H_2O$ solution under constant stirring.

The suspension thus formed with the dripping of alkaline aqueous NaOH solution to the $Zn[NO_3]_2.6H_2O$ solution was kept stirred for various hours at room temperature and then the solution was allowed to settle for 24 hours at room temperature. The supernatant liquid was discarded and the remaining infranatant was centrifuged for 20 minutes at 8000 roud per minute (RPM). The centrifuged material was then washed with distilled water and subsequently with alcohol. The washed product was dried at 700C for one hour in an incubator. The final product was calcined for 3 hours at 5000c. The yield of zinc oxide nano structure by this method was 91%.

The crystalline surface morphology of the prepared nano particles of zinc oxide was characterised using scanning electron microscope (JSM-6380A, JEOL Japan) (Figure 2) followed by elemental analysis using energy dispersive X-ray spectroscopy (EDX) (Figure 3). Fourier transform infrared radiation spectroscopy (Thermonicolet avatar 320 ATR) was used to identify any inorganic material. Delayed expansion was checked by electron micrometre (Mitutoyo, Japan).

Admixed, non-gamma type II dental amalgam (aristalloy 21) conforming to international standard ISO 1559:1995 later revised to ISO standard 24234:20154 was used. The mercury used was 99.99% pure and the ratio of dental amalgam alloy to mercury used was 1:1. The samples were prepared by mixing dental amalgam alloy and zinc oxide nanoparticles at different ratios and weight percentages of zinc oxide nano powder. The weights of all prepared samples were 1.5 grams measured using weight analytical machine with 0.0001-gram accuracy.

For delayed expansion, the samples were fabricated by manually mixing zinc oxide nano particles with dental amalgam alloy which were triturated with mercury using an electrical amalgamator. The triturated dental amalgam was compacted into Teflon mould 4 x 6 mm in dimensions. Delayed expansion was checked at 5 min, 30 min, 3 hrs, 6 hrs, 12 hrs and after 24 hrs.

Data was analysed using SPSS 22. The variance among the groups, was determined using one-way analysis of variance (ANOVA).

Results

Of the 180 samples, there were 90(50%) in control group A, and 45(25%) each in experimental groups B and C. Control and experimental groups behaved differently upon setting. A representative graph of linear dimensional change versus time of the three groups was developed (Figure 1).

The control group showed initial contraction from 5 minutes till 3 hours, but after that expansion was

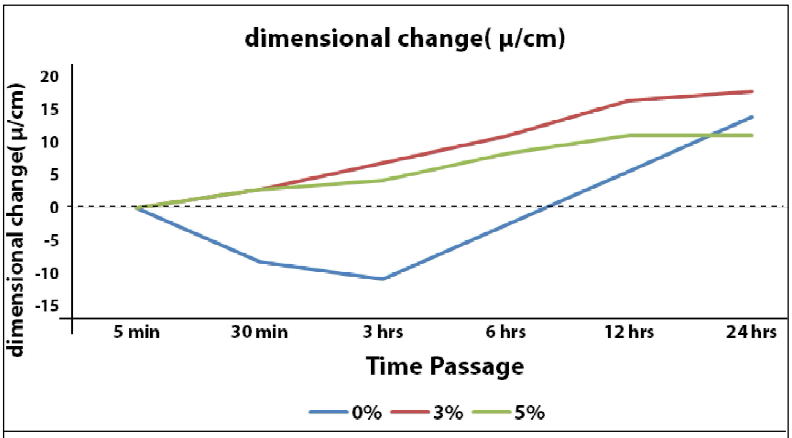

Figure-1: Graphical representation of linear dimensional change in three groups.

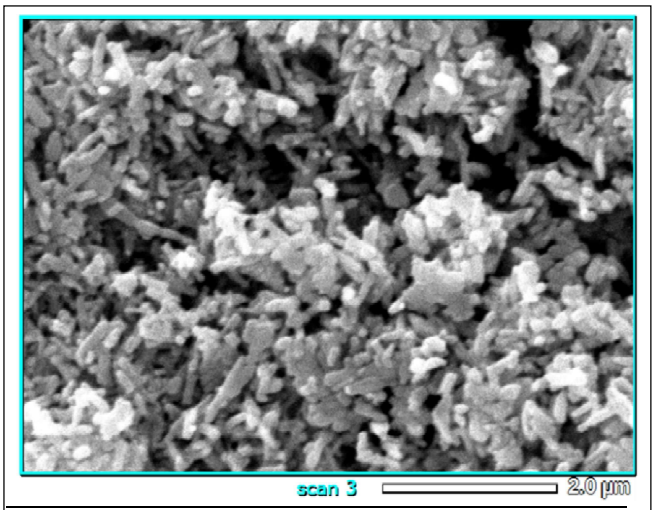

Figure-2: Scanning Electron Microscope (SEM) image of nano Zinc powder.

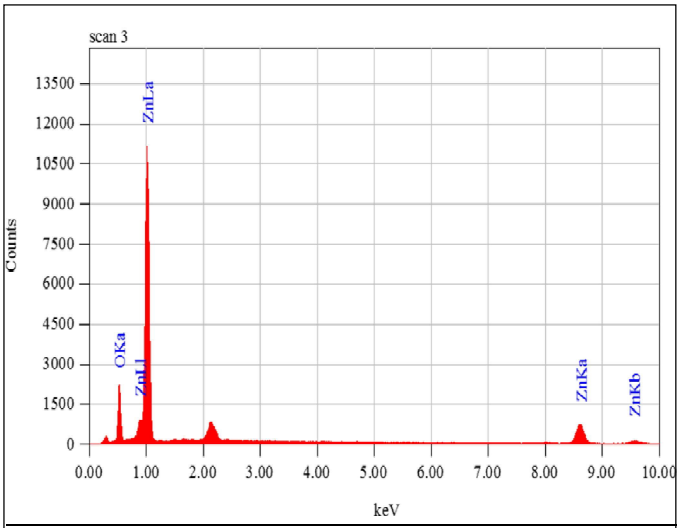

Figure-3: : EDX analysis of nano Zinc powder.

observed. All these variations noted were within the described range of 0-20 µ/cm.

Experimental subgroup B showed significantly more linear expansion then subgroup C ($p<0.05$). Both the experimental subgroups approximately achieved their entire linear expansion after 24 hours. Subroup B showed much faster dimensional change than that of subgroup C and resulted in much larger dimensional change at the end of the experiment. Whereas subgroup C showed dimensional change till 12 hours and after that no dimensional change was observed. Subgroup C showed minimal amount of dimensional change compared to subgroup B and control group A (Tables 1-2).

Table-1: Dimensional change of dental amalgam with time.

Concentration of zinc oxide	Time Passage (value in µ/cm)					
	5 min	30 min	3 hrs	6 hrs	12 hrs	24 hrs
Group A ... 0 wt. %	0	-8.25	-11	-2.75	5.5	13.75
Group B ... 3 wt.%	0	2.72	6.8	10.89	16.33	17.69
Group C ... 5 wt.%	0	2.75	4.12	8.25	11	11

Table-2: Percentages in accordance with the final dimensional change.

Concentration of zinc oxide	Time Passage					
	5 min	30 min	3 hrs	6 hrs	12 hrs	24 hrs
Group B ... 3 wt.%	0	15.3	38.4	61.5	92	100
Group C ... 5 wt.%	0	25	37.4	75	100	100

Discussion

The development of new materials on the length scale of approximately 1-100nm has become the focus of the investigations currently due to comprehensive progress9. These nano materials have unique properties and functions that are substantially different from those of bulk materials due to their small size and large surface area.[10] Parameters, such as size, distribution of size and morphology, may significantly alter the physical and chemical properties and its interaction with target biological areas.[11]

Among the nano materials with industrial relevance, zinc oxide stands out which is being used in various dental materials to improve their properties[12,13] with regards to its manufacturing. Different techniques are employed to produce these nano structures, such as thermal decomposition,[14] precipitation,[15] hydrothermal method,[16] vapour phase,[17] sol-gel,[18] molecular beam

epitaxy[19] and solo-chemical method.[20] Among the techniques employed, those belonging to the chemical routes are suitable for the preparation of zinc oxide nano structures at an industrial scale 20 since they are relatively cheap and provide a high uniformity of the final product.[20]

Keeping in mind the above-mentioned results, it is to be recalled that our previous basic understanding regarding the dimensional change of amalgam is that there should be slight expansion in the process of setting which will result in better adherence of the restorative material to the cavity walls.[22] In the current study, direct precipitation method was used for manufacturing nano zinc oxide,[23,24] for characterisation of surface morphology scanning electron microscope (SEM) and energy dispersive x-ray spectroscopy (EDX) was done.

Since the co-efficient of expansion of dental amalgam is larger than the teeth, an interface created by the contracted amalgam due to temperature drop may be compensated by the elasticity of tooth23. Because of this reason, ADA specification No 1 initially requires that dental amalgam expands only 3- 13 µ/ cm after 24 hours, which was later changed to 0-20 µ/cm.[4]

It is generally known that initial contraction occurs with all the conventional amalgams due to absorption of mercury by the alloy particles, which was again supported by the current study.[22,25,26]

Further research, however, is required regarding the mechanism behind the absence of initial contraction and effect on other properties of dental amalgam after nano zinc oxide incorporation.

The current study has its limitations as it used only the conventional non-gamma II amalgam. Besides, all experiments were carried out at room temperature, which means changes in other physical properties need to be evaluated further.

Conclusion

There was improvement in the dimensional stability of dental amalgam after the incorporation of nano particles of zinc oxide.

Disclaimer: None.
Conflict of Interest: None.
Source of Funding: None.

References

1. Featherstone J, Fontana M, Wolff M. Novel anticaries and remineralization agents: Future research needs. Los Angeles: SAGE Publications Sage CA; 2018.
2. Moynihan P, Makino Y, Petersen PE, Ogawa H. Implications of WHO Guideline on Sugars for dental health professionals. Comm Dent Oral Epidemiol 2018; 46: 1-7.
3. Georgieva M, Dimitrov E, Andreeva R, Nikolova T, Arnautska H, Sabeva E. Possible choices of materials and methods for restoration of permanent teeth in Pediatric Dentistry. Scripta Scientifica Medicinae Dentalis 2017; 3: 18-22.
4. Yahya N, Puspitasari P, Latiff NRA. Hardness improvement of dental amalgam using zinc oxide and aluminum oxide nanoparticles. Characterization and Development of Biosystems and Biomaterials: Springer 2013; 29: 9-32.
5. Mackey TK, Contreras JT, Liang BA. The Minamata Convention on Mercury: Attempting to address the global controversy of dental amalgam use and mercury waste disposal. Sci Total Envir 2014; 472: 125-9.
6. Mutter J. Is dental amalgam safe for humans? The opinion of the scientific committee of the European Commission. J Occup Med Toxicol 2011; 6: 2.
7. Sahani M, Sulaiman N, Tan B, Yahya N, Anual Z, Mahiyuddin WW, et al. Mercury in dental amalgam: Are our health care workers at risk? J Air Waste Manag Assoc 2016; 66: 1077-83.
8. Boris IK. A review for synthesis of nanoflowers, Recent Pat. Nanotechnol 2008; 2: 190-200.
9. de Vasconcelos BC, Bernardes RA, Cruz SML, Duarte MAH, de Magalhães Padilha P, Bernardineli N, et al. Evaluation of pH and calcium ion release of new root-end filling materials. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009; 108: 135-9.
10. Khurshid Z, Zafar M, Qasim S, Shahab S, Naseem M, AbuReqaiba A. Advances in nanotechnology for restorative dentistry. Materials 2015; 8: 717-31.
11. Khan I, Saeed K, Khan I. Nanoparticles: Properties, applications and toxicities. Arabian Journal of Chemistry 2019; 12: 908-31.
12. Shin SW, Song IH, Um SH. Role of physicochemical properties in nanoparticle toxicity. Nanomaterials 2015; 5: 1351-65.
13. Aydin Sevinç B, Hanley L. Antibacterial activity of dental composites containing zinc oxide nanoparticles. Journal of Biomedical Materials Research Part B: Applied Biomaterials 2010; 94: 22-31.
14. Hojati ST, Alaghemand H, Hamze F, Babaki FA, Rajab-Nia R, Rezvani MB, et al. Antibacterial, physical and mechanical properties of flowable resin composites containing zinc oxide nanoparticles. Dental Materials 2013; 29: 495-505.
15. Khalil MI, Al-Qunaibit MM, Al-Zahem AM, Labis JP. Synthesis and characterization of ZnO nanoparticles by thermal decomposition of a curcumin zinc complex. Arabian J Chem 2014; 7: 1178-84.
16. Sharma RK, Ghose R. Synthesis of zinc oxide nanoparticles by homogeneous precipitation method and its application in antifungal activity against Candida albicans. Ceramics Int 2015; 41: 967-75.
17. Ding J, Zhu S, Zhu T, Sun W, Li Q, Wei G, et al. Hydrothermal synthesis of zinc oxide-reduced graphene oxide nanocomposites for an electrochemical hydrazine sensor. RSC Advances 2015; 5: 22935-42.
18. Chen D, Zhang H, Hu S, Li J. Preparation and enhanced photoelectrochemical performance of coupled bicomponent ZnO? TiO2 nanocomposites. J Physical Chemistry C 2008; 112: 117-22.
19. Alwan RM, Kadhim QA, Sahan KM, Ali RA, Mahdi RJ, Kassim NA, et al. Synthesis of zinc oxide nanoparticles via sol-gel route and their characterization. Nanosci Nanotechnol 2015; 5: 1-6.
20. Coke M. Electronic properties of zinc oxide and related materials grown by molecular beam epitaxy: UCL (University College London); 2017.

21. Sornalatha DJ, Bhuvaneswari S, Murugesan S, Murugakoothan P. Solochemical synthesis and characterization of ZnO nanostructures with different morphologies and their antibacterial activity. Optik-Int J Light Electron Optics 2015; 126: 63-7.
22. Gusatti M, Rosário JA, Barroso GS, Campos CE, Riella HG, Kunhen NC. Synthesis of ZnO nanostructures in low reaction temperature. CHEMICAL ENGINEERING 2009; 17: 1017.
23. Yusan S, Bampaiti A, Aytas S, Erenturk S, Aslani MA. Synthesis and structural properties of ZnO and diatomite-supported ZnO nanostructures. Ceramics Int 2016; 42: 2158-63.
24. Sirelkhatim A, Mahmud S, Seeni A, Kaus NHM, Ann LC, Bakhori SKM, et al. Review on zinc oxide nanoparticles: antibacterial activity and toxicity mechanism. Nano-Micro Letters 2015; 7: 219-42.
25. Darvell B. Some studies on dental amalgam Part 2. Dimensional change. Surface Technology 1976; 4: 201-10.
26. NAGAI K, OHASHI M. Studies on the Dimensional Change of Dental Amalgams. J Nihon Uni School Dent 1967; 9: 1-19.