http://doi.org/10.33279/jkcd.v15i04.904

Original Article

COMPARISON OF THE MECHANICAL PROPERTIES OF DENTAL COMPOSITE AND ITS MODIFIED COUNTERPART WITH HYDROXYAPATITE

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ABSTRACT

Objectives: *This study compared mechanical properties of pure dental composite made with that of copper dope hydroxyapatite integrated in dental resin composite.*

Materials and Methods: *Dental resin composite with 2%, 5% and 8% Nano hydroxyapatite crystals doped in Copper was mechanically tested in comparison to dental resin composite manufactured manually having 70% Bis-GMA and 30% TEGDMA, Camphor quinine as a initiator and dimethyl aminoethyl methacrylate in a form of co-initiator. Flexural strength, Vickers hardness and values of compressive strength were evaluated.*

Results: *The mechanical tests revealed that as compared to dental composite manufactured in laboratory, the hydroxyapatite doped with copper dental composite had significantly better mechanical properties.*

Conclusion: *The Vickers's hardness, flexural strength and compressive strength of experimental dental composite increased with increasing percentage of hydroxyapatite nanoparticles added as a filler in a proportion of 3%, 5% and 8% with salinized silica in dental composite.*

Key words: *Dental composite, organic part, matrix, polymerization, resin component*

Cite as: Ahmad W, Khan A, Ahmad H, Ahmad F, Ahmad SA, Babar BZ. Comparison of the mechanical properties of dental composite and its modified counterpart with hydroxyapatite. Journal of Khyber College of Dentistry Dec 2025, Vol. 15, No. 4. http://doi.org/10.33279/jkcd.v15i04.904

INTRODUCTION

Since the beginning of 1970s, dental resin composite have been developed with greater emphasis on polymerization and it's filler content[1]. The primary components of dental resin composite primarily consist of co initiator, inorganic fillers part, and organic matrix. The primary organic component is the matrix component, polymerized by light cure mechanism and inorganic part made up of inorganic filler that is responsible for improving the mechanical properties. decreasing amount of matrix and increasing filler component will lessen the polymerization shrinkage produced in dental composite[2,3]. Various fillers have been used with various materials to offer good strength and ability to polish it readily[4,5].

The most common problems associated with dental composites were failure of restoration, presence of polymerization shrinkage, water sorption, marginal failures, occurrence of secondary caries, post-operative sensitivity, and micro-leakage[6]. Recurrent decay is a major issue, with dental resin composite experiencing higher rate than dental amalgam restorations[7]. Polymerization shrinkage

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Date Submitted: September 2025
Date Revised: October 2025
Date Accepted: November 2025

leading to problems such as marginal failures and micro-leakage phenomena[8]. Improper case selection, isolation, wear resistance, cavity preparation, placement of composites, curing, finishing, and polishing are factors that contribute to these problems[6]. Overall, these issues highlight the need for proper material selection, handling, and clinical techniques to minimize the problems associated with dental composites .

Problems were related with dental composites reducing their lifespan. Decrease mechanical properties including flexural strength, compressive strength, Vickers hardness and polymerization shrinkage are the main flaws that are responsible mainly for the failure of dental resin composite, despite the notable advancements in resin-based composites[9].

Various modifications were done to improve properties of dental composite. In recent times, dental composite resin based on silorane was developed containing cationic ring opening monomer system that is biocompatible, highly reactive with low polymerization shrinkage, making it resilient to temperature fluctuations in oral environment[10-12]. In other study, although depth of cure and polymerization shrinkage were not improved, silanization of silica filler with methacryloxy silane bonding agents improved the mechanical properties and monomer conversion in dental composites[13]. Modification was also done to improve mechanical properties of dental composite and results revealed that higher Vickers hardness and flexural modulus were demonstrated by dental composite combined with alumina nanoparticles; nevertheless, flexural strength was marginally reduced with filler loading[14].

Hydroxyapatite makes up majority of enamel and dentin. Additionally, it accounts for almost 95% and 60% of the enamel's and dentin's components. Additionally, hydroxyapatite being bioactive and biocompatible are found in human bone in a form of phosphocalcic crystals ($Ca_{10}(PO_3)_6(OH)_2$)[15].

To the best of our knowledge, no research has been done to examine and compare addition of HA in a form of percentages to dental composite with the pure dental composite made manually. Prior research has included nano-HA in dental restorative materials, and it has been discovered that this increases the materials' properties[16]. The flexural strength of experimental modified dental composites modified with nano-HA is increased when the nano-HA crystals are well dispersed at low loading mass fraction. However, when the loading of the nano-HA is higher, it may act as a defect in bundles, causing restorative material to fail[17]. This is in accordance to another recent study conducted by Chen et al[18].

MATERIALS AND METHODS

For the preparation of dental composite, 70% Bis-GMA and 30% diluent co-monomer i.e. TEGDMA (0.54 mole fraction) as a co-monomer was added Camphor quinone was added as a initiator and dimethyl aminoethyl methacrylate in a form of co-initiator was added to makeup the matrix component of dental composite. An Ethical approval from Institutional Review Board (IRB) of Khyber Medical University was obtained vide Ref. No. DIR/KMU-EB/DR/12-36 dated 04/12/20. 70% salinized silica was added as an inorganic filler to makeup the dental composite.

For the preparation of inorganic part i.e. filler component of dental composite, the silica was first sialinized. The sialinization process was performed by reacting 500 ml of ethanol with 465ml of distilled water to form465g of powdered silica. Consequently, 300ml of ethyl alcohol was reacted with 174 mmol of octyltriethoxysilane followed by stirring for 45 min so that silca particles were fully coated with silane. Condensation reaction was carried out with reaction flask refluxed for 3 hours at 78 °C followed by stirring. The reactant was then washed with ethanol and centrifuged.

For the preparation of modified dental composite, hydroxyapatite nanoparticles were added in concentrations of 3%, 5%, and 7% to Dental Composite and samples were cured

For the Vickers hardness test, ISO standard 6507protocol were followed, and samples of dimensions (6mm ×4mm) were prepared in mold followed by curing of the sample with the blue light and finishing.

For the flexural strength test, ISO 4049, 2000protocols were followed with the samples of dimensions (2o×2×2 mm) were placed in mold followed by curing, trimming and polishing. The samples were then recovered.

For the compressive strength test, ISO standard 991711 protocols were followed with samples in mold of dimensions (6mm ×4mm). These samples after curing and polishing were placed in universal testing machine.

The analysis of variance (ANOVA) was used for the statistical assessment of data collected.

RESULT

The mean values along with standard deviation values of compressive strength, flexural strength and Vickers hardness are given below.

The compressive strength results of dental composite were positive with the strength increasing as the percentage of hydroxyapatite was increasing from dental composite to 2%, 5% and 8%. The mean value along with standard deviation of dental composite was found to be 22.02 ± 1.58. The mean along with standard deviation value for 2% hydroxyapatite in dental composite was 28.41 ± 2.23; for 5% was 30.18 ± 1.41 and that of 8% was 60.15 ± 2.236.

The Flexural strength results of dental composite were positive with the strength increasing as the percentage of hydroxyapatite was increasing from dental composite to 2%, 5% and 8%. The mean value along with standard deviation of dental composite was found to be 18.12 ± 2.236. The mean along with standard deviation value for 2% hydroxyapatite in dental composite was 23.42 ± 2.121; for 5% was 28.12 ± 4.301 and that of 8% was 31.25 ± 0.707.

The Vicker hardness test results of dental composite were positive with the strength increasing as the percentage of hydroxyapatite was increasing from dental composite to 2%, 5% and 8%. The mean value along with standard deviation of dental composite was found to be 15.13 ± 1.93. The mean along with standard deviation value for 2% hydroxyapatite in dental composite was 17.64 ± 0.60; for 5% was 22.44 ± 0.223 and that of 8% was 27.15 ± 2.40.

DISCUSSION

The addition of hydroxyapatite has been shown to increase their mechanical properties[17] In one study, the dispersion of HAP nanofibers in a dental matrix led to an increase in biaxial flexural strength compared to composites filled with untreated HAP nanofibers. Another study found that resin composites reinforced with HAP nanofibers and silica nanoclusters showed reduced polymerization shrinkage and enhanced mechanical properties. Additionally, the addition of hydroxyapatite with graphene nanoparticles to unfilled monomer mixtures increased the flexural strength and Young's modulus of the material. These findings suggest that the incorporation of hydroxyapatite into dental composites can improve their mechanical properties.

Compressive Strength

The significance of compressive strength is emphasized by biting forces. Increase compressive strength means that a material is hard enough to bear compressive strength under a given load applied[19]. The group containing highest compressive strength was dental composite having hydroxyapatite content of 8%, while the group containing hydroxyapatite of 3% has the lowest strength.

Additionally, Ana Josefina Mojarras-Ávila et al. focused on increasing the compressive strength of dental composite, discovered that the kind of copolymer and monomer concentration affect both compressive strength and modulus of elasticity. The mechanical characteristics of the dental resin composite are enhanced by enhancing the amount, size, and shape of filler[20].

Bhanu Pratap et al. modified dental composite by adding silica to filler component and revealed that it's addition (i.e 9%) to dental composite increased compressive strength by 150 MPa and reduces the

Table 1: Compressive strength with Standard Deviation of Dental Composite Samples

	control, N = 5	E1, N= 5	E2, N=5	E3, N=5	P value
Compressive strength (MPa)	22.02(1.58)	28.41(2.23)	30.18(1.41)	60.15(2.236)	<0.001

Table 2: Flexural strength with Standard Deviation of Dental Composite Samples

	control, N = 5	E1, N= 5	E2, N=5	E3, N=5	P value
Flexural strength (MPa)	18.12(2.236)	23.42(2.121)	28.12(4.301)	31.25(0.707)	<0.001

Table 3: Vicker Hardness strength with Standard Deviation of Dental Composite Samples

	Control, N = 5	E1, N= 5	E2, N=5	E3, N=5	P value
Vicker hardness (MPa)	15.13(1.93)	17.64(0.60)	22.44(0.223)	27.15(2.40)	<0.001

void part that was in accordance with our study[21].

Shiv Ranjan Kumar et al. added nanoalumina filler particles in dental composite and concluded upto 16% increase in compressive strength between the basic dental composite and modified dental composite[22]. Bhanu Pratap et al. added ZnO as a filler to dental composite and concluded increase in its mechanical properties as compared to basic dental composite[23].

Vicker Hardness

The amount and size of filler particles have significant impact on hardness of dental composite. According to this study, Vickers hardness rises on increasing hydroxyapatite concentration from 2% to 5% and subsequently 8%.

By incorporating fillers like zirconia or silica in dental resin composite's, Berthelot JM et al. were able to enhance the material's mechanical characteristics in comparison to unreinforced polymers[24].

After working on dental composite surface polishing, S. H. Park et al. concluded that celluloid fninishing of dental composite was having significant impact on mechanical properties i.e. vicker hardness of dental composite[25].

Chinelatti MA et al also worked on improving the hardness of dental composite and concluded that hardness of micro. And minifill composite were increased then flowable composites.These studies were similar to our study and the mechanical properties were improved when fillers were added to dental composite[26].

FlexuralStrength

It is more common to use flexural strength tests rather than diametral tensile tests because they produce a primary tensile stress on the specimen's under surfaces[27].

From the first to last experimental dental composite group, the flexural strength was increased. The experimental dental composite group with 3% hydroxyapatite showed the least strength when compared to dental composites with 5% and 8% hydroxyapatite. Thus, adding hydroxyapatite to dental composite will improve its bending strength or flexural strength.

AysuKarakaşAydınoğlu et al. worked on dental composites to improve flexural strength and found out that salinization process affects organic phase and inorganic interface of silica with dental polymers that results in improved mechanical properties[28].

Ameenah Saad Alansy et al. modified the dental composite by adding ZnO/boron nitride as filler with the conclusion that there was no significant difference between control group with experimental dental composite[29].

CONCLUSION

The Vickers's hardness, flexural strength and compressive strength of experimental dental composite increased with increasing percentage of hydroxyapatite nanoparticles added as a filler in a proportion of 3%, 5% and 8% with salinized silica in dental composite.

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CONFLICT OF INTEREST
Authors declare no conflict of interest.
GRANT SUPPORT AND FINANCIAL DISCLOSURE
None declared.

AUTHORS' CONTRIBUTION

The following authors have made substantial contributions to the manuscript as under:

Conception or Design:	WA, AK, HA, FA, SAA, BZB
Acquisition, Analysis or Interpretation of Data:	WA, AK, HA, FA, SAA, BZB
Manuscript Writing & Approval:	WA, AK, HA, FA, SAA, BZB

All the authors agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.