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A Pilot in Vitro Comparison of Compressive Resistance Among Selected Dental Restorative Materials

Nahida Salh Hamad[1] , Nabeel Abdulrazzaq Fattah[2]

ABSTRACT

B**ackground and Objectives:** To demonstrate the inherent variations between various brand products, a first-time report on the compressive strength of a few commercially available dental restorative materials of particular interest is provided.

Methods: The compressive strength of three different types of materials—zinc phosphate cement, amalgam, and resin composite— wa measured using a universal testing machine. By using laboratory molds to fabricate specimens in compliance with manufacturer specifications, unstandardized dimensional variations were produced that closely resembled the original experimental conditions. The analysis was conducted using descriptive statistics and ANOVA.

Results: Zinc phosphate cement (1010 N) and amalgam (527.5 N) had significantly lower average compressive strengths than composite resin (3560.8 N). The most significant difference between the amalgam and resin composite groups was demonstrated by the significant standard deviations.

Conclusion: The results seem to support notable performance variability within material classes and, more significantly, their remarkable versatility within the limited parameters of this pilot study.

That is to say that the specific commercial formulation and material are equally potent as the material class itself. These early results emphasize the requirement for adequate product selection and suggest worthwhile directions for more controlled future work.

Keywords: Amalgam, Compressive Strength, Composite Resin, Dental Materials, Zinc Phosphate Cement

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Affiliation Info

[1]College of Dentistry, Hawler Medical University, Kurdistan Region, Iraq.
[2]College of Medicine, Hawler Medical University, Kurdistan Region, Iraq.
Corresponding Author: Nahida Salh Hamad.
Email: nahida22salh@gmail.com

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INTRODUCTION

The clinical success of direct dental restorations is primarily a function of their mechanical performance, the compressive strength being the key parameter by reason of the masticatory loads they bear.[1,2] Since there are international standards for testing dental materials under idealized conditions.[3,4] The actual clinical behavior of a material also depends on the particular commercial product on which the practitioner is working. Dental amalgam, due to its durability, and resin composite, due to its popularity for esthetic reasons, are the paradigms of old and new direct restoratives, respectively.[5,6]

Zinc phosphate cement, although used mostly as a luting agent, is a convenient historical foundation for mechanical contrast.[7] It is certain that within the broad material categories, there exist differences in composition between different commercial products—e.g., filler content of composites or alloy content of amalgams—that can significantly affect their mechanical properties.[8] Nevertheless, relative data regarding the performance of individual commercially available brands are usually restricted. Full standardized, large-scale studies are costly, hence, pilot studies are useful for early screening and trend detection, which deserve further research.[9]

This pilot study was conducted as a preliminary study to reach two principal goals: initially, to carry out a preliminary comparative evaluation of the compressive strength of a variety of readily available commercial resin composite and amalgam types, using the zinc phosphate cement as the reference point; Second, to determine the degree of variability characteristic of these material groups. The findings aimed at giving initial information to clinicians and guiding the construction of more comprehensive future studies.

METHODS

Study Design

The study utilized an in vitro experimental study design to carry out an initial comparison of the compressive strength of three dental restoratives: amalgam, resin composite, and zinc phosphate cement. The study was designed as a pilot study to determine initial trends and variability among products that are commercially available.

Materials

The following materials were used within this study:

Amalgam: Four commercially available products of amalgam were used: BMC Dental, Cavex AV-Alloy, Via Dent, and Novalgam NG. All were received from their respective suppliers.

Resin Composite: Six commercially available resin composite products were tested: Toku Yama (Japan), Dentsply Sirona Spectra (STHV) A, G-aenial TM (Japan), DENU, Dline, and ITENA (France). All products were obtained from their respective suppliers.

Zinc Phosphate Cement: One zinc phosphate cement product (Master-Dent, USA) was tested as a reference material, obtained from its supplier.

The specific product brands and distributors are detailed in Table 1.

Sample Preparation

Specimens were prepared according to manufacturers' instructions using available laboratory molds:

Amalgam: Condensed into cylindrical molds (4.85 mm diameter × 12 mm height)

Resin Composite: Placed incrementally into cylindrical molds (9 mm diameter × 8 mm height) and light-cured using a Ritter OPM-LED-G unit, with the light intensity verified with a radiometer to be within the 1000-2000 mW/cm² range, for 20 seconds per increment.

Zinc Phosphate Cement: Placed into cylindrical molds (7 mm diameter × 12 mm height)

All samples were allowed to set/cure per manufacturer recommendations, then polished with 400-1200 grit abrasive papers to ensure parallel surfaces.

Compressive Testing

Testing was performed using a Gunt WP300 universal testing machine (20 kN load cell) at a crosshead speed of 0.5 mm/sec until failure. Maximum load at failure was recorded in Newtons (N). All tests were conducted at room temperature (15°C).

Statistical Analysis

Descriptive statistics were computed for compressive resistance (Load in N). One-way ANOVA compared the amalgam and resin composite groups, and Tukey's HSD was used for post-hoc comparisons ($\alpha = 0.05$). Zinc phosphate cement ($n = 1$) was excluded from the statistical analysis. One-way ANOVA contrasted amalgam and resin composite groups, and Tukey's HSD post-hoc comparisons ($\alpha = 0.05$). Zinc phosphate cement ($n = 1$) was not included in the statistical analysis. Analysis was conducted with SPSS version 26.

Methodological Considerations as a Pilot Study

The study was executed as a pilot investigation, with parameters chosen for feasibility and the examination of emerging trends:

Sample Size: Small sample sizes (amalgam n=4, composite n=6, cement n=1) are sufficient for preliminary observations of differences but are inadequate for generalization.

Specimen Preparation: Non-standardized sizes are more accurate representations of actual mold availability than ISO standardization.

Test Temperature: A control standard is 15°C, which is room temperature. The author's own 30–37°C is a clinical utility that should be used with caution in future work. Testing at 37°C is a crucial area for future focus to enhance clinical translatability of results.

Table 1. Materials used in this study

#	Materials	Product Company	Imported by the Company	Production date	Expiration Date
1	Resin Composite	Cavex AVAlloy	Snow Company	11-2023	11-2026
2	Resin Composite	Dentsply Sirona Spectra A	Sky Dent	1-2022	1-2025
3	Resin Composite	G-aenial TM	Almass Alwardy	7-2023	7-2025
4	Resin Composite	DENU	Shiny Dent	3-2024	3-2026
5	Resin Composite	Dline	Dentine Company	24-4-2024	23-4-2027
6	Resin Composite	ITENA	Yohan Company	4-2022	4-2025
7	Amalgam	Cavex AVAlloy	Almas Alwardy	9-2023	11-2027
8	Amalgam	Cavex AVAlloy	Shiny Dent	5-2023	6-2027
9	Amalgam	Via Dent	NewDent Company	3-2023	3-2027
10	Amalgam	Novalgam NG	Sky Dent	4-2021	4-2026
11	Zinc Phosphate Cement	Master-Dent USA	NewDent Company	4-2024	7-2026

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Range of Material: Zinc phosphate cement as a reference point alone, with proper consideration of its statistical limitations.

Ethical consideration

This study was reviewed and approved by the scientific research ethical committee of the College of Dentistry, Hawler Medical University, Kurdistan Region, Iraq. Ethical clearance was guaranteed under Reference number HMUD, 2425195 on 5/1 /2025.

RESULTS

This study assessed the compressive strength of three dental materials: amalgam, resin composite, and zinc phosphate cement. The results are shown below.

Descriptive Statistics

The descriptive statistics for compressive resistance (maximum load at failure, in Newtons N) are summarized in Table 1.

Table 2. Descriptive statistics for compressive resistance (Load in N)

Material	N	Mean (N)	Standard Deviation (N)	Range (N)
Amalgam	4	527.5	365.2	820
Resin Composite	6	3560.8	3088.7	7020
Zinc Phosphate Cement	1	1010	-	-

Table 2 shows that the resin composite had the highest mean compressive resistance (3560.8 N), which was much higher than that of amalgam (527.5 N) and zinc phosphate cement (1010 N). The large standard deviations show that there is a lot of variation in both the amalgam and resin composite groups.

Statistical Analysis

One-way ANOVA showed that there was a statistically significant difference in compressive resistance between amalgam and resin composite ($F(1, 8) = 15.158$, $p = 0.005$). Post-hoc analysis utilizing Tukey's HSD test revealed that the resin composite exhibited significantly superior compressive resistance compared to amalgam ($p < 0.001$).

Observations

Variability: There was a lot of variation in compressive resistance within both the amalgam and resin composite groups, as shown by the high standard deviations and wide ranges. This was one of the most important things we learned from this pilot study.

Zinc Phosphate Cement: The compressive resistance of zinc phosphate cement was a single data point (1010 N). Therefore, it was excluded from statistical comparisons and is presented for qualitative reference only.

DISCUSSION

This pilot study presented an initial comparison of compressive strength of certain commercially used brands of dental amalgam and resin composite. The most valid finding was the wide variability observed within each material category, pointing towards the predominance of product-specific formulation over material category designation. The greater mean compressive strength of resin composites concurs with engineering requirements of contemporary restorative products, which depend on high filler content and novel matrices to resist occlusal forces.[6,7] The variance observed among composites may also result from differences in polymerization efficiency and curing light parameters[10,11] But of most concern in this group is the substantial variation of values (Range: 7020 N). The variance is due to variations in proprietary mixes in products being analyzed (Toku Yama, Dentsply Sirona, G-aenial, DENU, Dline, ITENA), i.e., type of filler, filler load %, and resin matrix composition.[6] This finding indicates that not all "composite resins" perform equally, and clinical selection should be informed by specific performance data.

In contrast, the amalgam group possessed below optimum compressive strength and the widest variability. This means that alloy composition variability, particle shape, and mercury content variability between different commercial brands (BMC Dental, Cavex AVAlloy, Via Dent, Novalgam NG) can determine the properties of the set material widely.[5] Variation in a certain product, as in the case of the Via Dent amalgam, is an indication of the possible influence of such product variables.

Introduction of the single data point of zinc phosphate cement compressive strength (1010 N) is given qualitatively, but not to compare quantitatively. That amount is equivalent to its well-known properties as a luting agent.[8] and helps determine the performance of the restorative materials.

When compared with other published works, the current findings show both alignment and divergence. Somani et al.,[12] reported that nanocomposite resin (Filtek Z350) exhibited the highest mechanical properties among the tested materials, followed by amalgam and Zirconomer. Their results support the present finding that resin-based restorations demonstrate superior compressive strength compared with amalgam. Similarly, Vaithyalingam et al.,[13] found that modern restorative materials such as Cention N and composite resin exhibited higher compressive and flexural strengths than traditional materials, confirming that resin-based systems have evolved to meet functional stress requirements effectively. In a different study,, Fousiya et al.,[14]highlighted the influence of curing mode and formulation on mechanical performance by finding that dual-cured Cention N exhibited higher compressive and flexural strength than its self-cured counterpart.

.According to ISO standards, zinc phosphate cement's known microstructural brittleness and limited mechanical capacity are consistent with its compressive resistance value of 1010 N.According to ISO standards 9917-1[15,16]

Overall, the findings of the current pilot study, which revealed that composite resin had the highest compressive resistance (3560.8 N) in comparison to amalgam (527.5 N), are in line with the general trend in the literature that suggests sophisticated composite formulations can match or even exceed amalgam in mechanical strength. However, due to variations in brand formulation, filler technology, and testing methodology, some variation remains across studies. The mechanical behavior of restorative materials is product-specific and cannot be generalized based solely on material class, which is highlighted by this variability. These results demonstrate that the composition and filler properties of restorative materials have a significant impact on their mechanical behavior, which is in line with accepted material science principles covered by Anusavice et al.[17]

INTERPRETATION IN PILOT STUDY CONTEXT

Determinable clinical conclusions are not possible due to the main limitations, which include a small sample size, a lack of standardization, and variable test room temperature. These, however, do not negate the primary point, which is that different commercial pairs of the same kind of material differ greatly from one another. This kind of change is a significant factor that requires further research because it might already exist in an initial condition. To measure these variations and their clinical relevance, future research should replicate the results with bigger sample sizes, standardized ISO instruments, and better representative oral conditions.

CONCLUSION

Significant differences in compressive strength between a few chosen dental restorative materials were clearly demonstrated by this pilot study. The amalgam and resin composite groups' differences from one another were the most intriguing aspect, but the resin composites performed best when combined. This suggests that formulation and brand have a significant impact on mechanical properties. Clinicians should understand that choosing the right materials and using products with proven superior mechanical properties are important.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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