

## Exploration of the Customized Fixtures for the Evaluation of Three-point Bending Strength of Dental Resin Composites

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### Abstract

**Introduction:** This study aimed to devise customized fixtures for the evaluation of three-point bending strength (TPBS) of resin-based dental composites (RBCs).

**Materials and Methods:** A cube-shaped jig made out of wood with dimensions of 105×105×101 mm was prepared in this study. A 20-mm-diameter hole was made in the center of the wooden jig. In addition, a stainless steel probe with 175mm length, 3mm thickness, and 2 mm width was fabricated and then fitted in the upper gripping crosshead of the universal testing machine. Subsequently, bar-shaped specimens of two commercial RBCs, namely Filtek Z350 XT Supreme Ultra Universal (Z350) and Premium Nano-Hybrid Composite (PN) were placed over the center of the jig hole and subjected to TPBS test in accordance with ISO 4049 standards protocol. **Results:** The mean TPBS values of Z350 and PN RBCs were 82 and 86 MPa, respectively. Moreover, the standard deviation values for both mean TPBS values were low indicating the homogeneity of the findings and associated reliability of the employed fixtures.

**Conclusion:** The fixtures for the TPBS test of RBCs were successfully designed and developed which would likely facilitate the researchers with a mechanical characterization of dental materials. A machine used for the testing of large industrial materials other than small dimensional dental materials can now be used to test TPBS of RBCs according to ISO 4049 with the help of the invented economical fixtures. This will enhance the quality of teaching and learning of materials science in developing countries.

**Keywords:** Customized fixtures, Fixtures, Resin-based composites, Three-point bending test, Universal testing machine, wooden jig

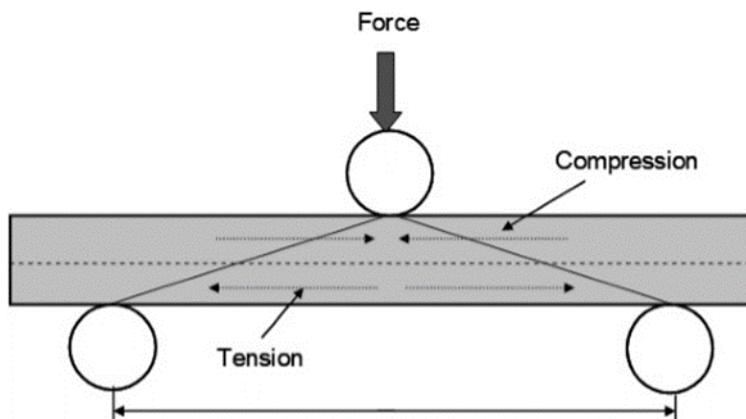
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### Introduction

In restorative dentistry, the utilization of direct resin composite restorations is increasing due to their superior aesthetics and no mercury toxicity in the amalgam counterpart (1). The mechanical integrity of restorative materials is considered as a key requirement for long-term clinical success. Therefore, the investigations considering the mechanical properties of these materials are highly clinically relevant (2). Various mechanical properties of resin-based composites (RBCs), namely strength (3), hardness (4), wear (5), creep (6), fatigue (7), and toughness (8) have been determined by the investigators; however, static-load-to-failure strength testing is being commonly employed worldwide (2). The possible reasons for the frequent utilization of strength testing could be its lower cost and relatively easier methodology, compared to other mechanical property testing methods. In the oral cavity, dental filling materials encounter several stresses due to the three-dimensional mechanics of mandibular movements. Accordingly, flexural strength is considered as a substitute for strength testing since it produces shear, tensile, and compressive stresses during the test (9). Flexural strength can be tested by several methods, namely a two-point bending test, a

three-point bending test (TPBT), and a four-point bending test. The TPBT is being the most frequently used method for the evaluation of RBCs owing to the recommendations by the International Standards Organization (ISO, 4049) (10). The bar-shaped specimens (25 mm length, 2 mm width, and 2 mm thickness) are fabricated and tested at the crosshead speed of  $0.75 \pm 0.25$  mm/min after placing the specimens at the support span of 20 mm and loading with a knife-edge indenter at the midpoint. The stresses produced in the specimen include compressive and tensile on the upper and lower halves, respectively (Fig. 1). In material

testing, the laboratories in developing countries (i.e., Pakistan) utilize the universal testing machines (UTM); however, their fixtures do not meet the requirements of dental research since the specimen size recommended by different universal standards is relatively small. Therefore, it is not feasible to employ such machines for the characterization of dental restorative materials. As a result, this study aimed to devise customized fixtures for the evaluation of three-point bending strength (TPBS) which may help the researchers utilize such machines for the strength testing of RBCs.



**Figure 1.** Schematic illustration of the three-point bending test showing the tensile and compressive stresses in lower and upper halves of the specimen, respectively.

### Materials and Methods

This study included two commercial RBCs, namely Filtek Z350 XT Supreme Ultra Universal (SU) (Z350); 3M ESPE and Premium Nano-Hybrid Composite (PN); Coltene Nt Premium. For each RBC, 5 bar-shaped specimens (25mm×2mm×2 mm) were manufactured in accordance with ISO 4049 (10). The specimens were stored for 24 h in distilled water at 37°C before the TPBS test. Subsequently, the specimens were blotted dried and subjected to test using a UTM (Instron 4301; England Serial Number: H1853) at a cross-head speed of  $(0.75 \pm 0.25)$  mm/min. The UTM was installed at the Pakistan Council of Scientific and Industrial Research, Karachi, Pakistan. It is worth mentioning that it was suitable for specimens having dimensions of 80mm×5mm×3mm; therefore, it did not fulfill the requirements of the ISO 4049 for TPBS testing. In order to follow the ISO 4049 standard protocol for testing RBC specimens, the fixtures were tailored to serve the purpose in the most appropriate way. A cube-shaped jig was made out of wood (wooden jig) with dimensions of 105 mm×105 mm×101 mm in this study (Figure 2a). The compressive strength of the tested wood was estimated at 25 MPa. Moreover, the

modulus of elasticity of the prepared wooden jig under flexure was obtained at 6.73 kN/mm<sup>2</sup>. This strength is adequate enough to give reliable results. Furthermore, a 20-mm-diameter hole was made in the center of the wooden jig (Fig. 2b). It was assumed that the distribution of load would be uniform either supported at a circular or rectangular span. This diameter was the span between the supports for testing RBC specimens (Figure 3). A stainless steel probe with 175mm length, 3mm thickness, and 2 mm width was also fabricated in this study. The probe was fitted in the upper gripping crosshead of the UTM (Fig. 4a). An RBC specimen was placed in the center of the jig hole in a way that 10% (2.5mm on each end of the jig hole) of the specimen located beyond the supports on each end of the hole, as per the criteria for beam mechanics (Fig. 4b). After positioning the specimen, the test was run and the probe exerted load in the center of the specimen leading to its fracture. Subsequently, the failure load was recorded and the mean TPBS values were calculated in accordance with Equation 1 using Microsoft Excel, 2010.

$$\text{Equation (1): } \sigma = \frac{3PL}{2wb^2}$$

where P denotes maximum load applied on the specimen (N), L indicates the support span (20mm), w signifies the width (2mm), and b presents the height (2 mm) of the

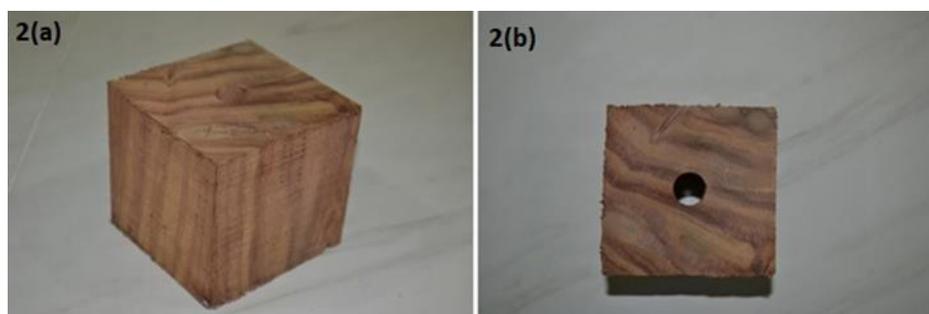
specimen. The data were analyzed in SPSS software (version 21).

### Results

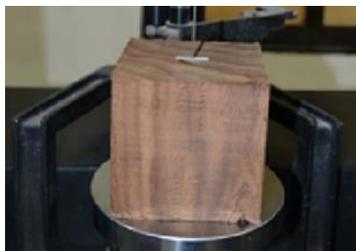
The mean±SD TPBS values of Z350 and PN RBCs were estimated at 82±2.7 and 86±0.8MPa, respectively (Table I).

**Table I:** Three-point bending strength of the two resin-based dental composites tested in the current study

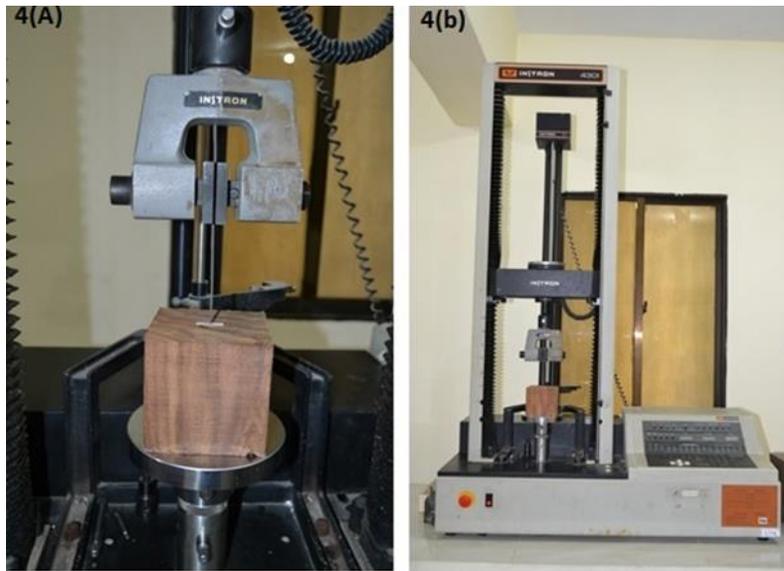
Resin-Based Composites	Mean Three-Point Bending Strength
Z350 RBC	82 (2.7)
PN RBC	86 (0.8)



**Figure 2.** Wooden Jigs, Cube-shaped wooden jig (2a), Top of the wooden jig with a hole in the center (2b)



**Figure 3.** Resin-based dental composite specimen over the span



**Figure 4.** Probe fixed to the upper grip crosshead (4a), complete assembly showing specimen with probe fixed to the upper grip crosshead of universal testing machines (4b)

### Discussion

Table I summarizes the mean $\pm$ SD TPBS values of RBC specimens. The SD values for both TPBS of RBCs are low indicating the homogeneity of the results, and therefore, the reliability of the utilized fixtures. There were also no substantial differences between the RBCs regarding their mean TPBS values which could be attributed to their comparable filler content. ISO 4049 (10) has set a minimum flexural strength of 80 MPa for polymer-based filling materials mandatory for restorations involving outer occlusal surfaces. The dental composites were tested in this study within acceptable limits. The main aim of this study was to explore suitable fixtures for the evaluation of TPBS of RBCs. Although UTMs are available in different institutes/industries for the evaluation of TBPS across Pakistan, these machines are not meant for dental specimens because of their relatively small sizes. On the other hand, they can be used for industrial engineering purposes. This limitation is likely to create huge obstacles for researchers in this country (i.e., Pakistan). The homogeneity of results suggests the reliability of the fixtures employed in the

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Current study. Moreover, the outcomes will be considered valid as there was no deformation of the jig occurred during testing which is a criterion of successful mechanics of the machine according to the latest literature (9).

Therefore, the machine used for testing of large industrial materials other than dental materials can now be used to test TPBS of RBCs according to ISO 4049 with the help of the invented fixtures. It is also worth mentioning that these fixtures are very economical and easy to fabricate.

### Conclusion

The fixtures for the TPBS test of RBCs were successfully designed and developed at the lowest cost possible. The consistency of TBPS results confirmed the reliability of fixtures. The developed fixtures are likely to enhance the quality of teaching and learning of materials science and engineering in developing countries.

### Conflict of Interest

The authors have declared no conflict of interest for present study.

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