Volume 3, Issue 7, 2025

Frontier in Medical & Health Research

ISSN: (e) 3007-1607 (p) 3007-1593

# COMPARISON OF IMPACT STRENGTH OF MICROCRYSTALLINE CELLULOSE REINFORCED DENTURE BASE ACRYLIC RESIN WITH AND WITHOUT THERMOCYCLING

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DOI: https://doi.org/10.5281/zenodo.17213734

**Keywords**
*Denture base, Polymethyl methacrylate, Micro crystalline cellulose, Impact strength, Thermocycling.*

**Article History**
*Received: 05 July 2025*
*Accepted: 05 September 2025*
*Published: 20 September 2025*

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## Abstract

*Objective: This study sought to investigate the impact strength of polymethyl methacrylate when reinforced with varying quantities of microcrystalline cellulose (MCC) with and without thermocycling in vitro. Materials and Methods: A total of 30 meticulously samples were prepared and tested according to the ISO 179A1:2005 specifications. The control group was prepared, following the manufacturer's instructions, with no MCC reinforcement. Experimental groups were categorized into two sub-groups, reinforced with 2% and 5% MCC. The samples from each group were further divided into two sub-groups (with thermocycling and without thermocycling), while half of the samples from each sub-group (n=5) were thermocycled for 5000 cycles at 5 °C and 55 °C with a dwell time of 30 sec on each cycle. The other half of each group (n = 5) were left submerged in water for 48 h without being thermocycled. Specimens were separately labelled and subjected to impact strength testing using Zwick pendulum impact tester. Results: Prior to thermocycling, the addition of MCC to the acrylic denture base resin significantly increased its impact strength, as supported by a One-Way ANOVA that demonstrated a significant difference in impact strength proportional to the amount of added cellulose ($P \leq 0.05$). After thermocycling, group B1, reinforced with 2% MCC, showed the highest impact strength as compared to the control group A1 and group C1, reinforced with 5% MCC. Conclusion: The impact strength of the 2% cellulose-reinforced group exceeded that of control group, both before and after thermocycling. Conversely, the impact strength of the 5% cellulose-reinforced group was lower than other groups, as the MCC amount was increased, the impact strength decreased before and after thermocycling.*

## INTRODUCTION

For the prosthetic replacement of missing teeth, a variety of methods and materials are available (Rahman, 2016). Polymethyl methacrylate (PMMA) offers various advantages, including good aesthetics

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ISSN: (e) 3007-1607 (p) 3007-1593

(Klironomos et al., 2015), mobility, affordability, ease of manufacture (Chintalacheruvu et al., 2017), and low density (Chintalacheruvu et al., 2017). However, PMMA also has a number of drawbacks, including poor strength (Gad et al., 2017), susceptibility to deformation, and low heat conductivity. Clinical failures are most commonly attributed to factors like flexural characteristics, low tensile strength, compressive strength, and impact strength (Rahaman et al., 2019).

Denture fracture represents one of the most common difficulties that denture wearers and dentist's encounters (Saeed et al., 2020). It is closely associated with material properties, technological characteristics, and the stresses that dentures must withstand (Sanjay et al., 2017). Therefore, incorporating modifiers such as copolymers, cross-linkers, and rubber components (e.g., butadiene-styrene) into acrylic resin composition can increase impact strength (Alhareb et al., 2017). Several methods have been explored to enhance strength, the most popular of which is fiber reinforcement, which can be natural or synthetic (Sanjay et al., 2017). Natural fibers reinforcement is preferred over synthetic counterparts because of their biodegradability and biocompatibility (Pickering et al., 2016). For more than 30 years, these impact resistant base resins have been available in market.

However, there is limited information regarding the impact-resistant effects of adding fibers and rubber inclusions to acrylic resin, it is crucial to understand the mechanical characteristics of impact resistance of acrylic resins. These additions (fibers and rubber) have unknown effects on stiffness, microstructure, and deformation behavior in shock-bending experiments (Gad et al., 2017). According to John et al., (2015), Micro crystalline cellulose (MMC) can be used as a lightweight substitute to commercial resins based on synthetic fiber-reinforced dentures. MCC is a white, biodegradable, non-fibrous, odorless, largely depolymerized crystalline powder obtained by the hydrolysis of cellulose (Rahaman Ali et al., 2019).

The oral cavity is in contact with food when chewing, and the most crucial effect is due to abrupt temperature changes, such as chewing hot food and drinking cold beverages, which can impair the mechanical qualities of the basic denture resin (Nidal et al., 2014). The process of thermocycling during denture production is utilized to mitigate the influence of temperature change on denture base acrylic resin (Andrade de Freitas et al., 2018). Rahaman Ali et al., 2019, emphasized that the impact, compression, and tensile strengths of denture base resins modified with Micro crystalline cellulose should be evaluated.

The aim of this study was to investigate the impact strength of PMMA reinforced with various quantities of Micro crystalline cellulose with and without thermocycling in vitro.

## 1. Material and Methods

### 1.1 Specimen preparation

Samples were prepared using a stainless-steel master mold (80 mm long, 10 mm wide, and 4 mm thick), in accordance to ISO 179A1:2005 specifications, as shown in Figure 1., Subsequently, three groups of samples were molded into rectangular shapes. To create the control group (Group A), PMMA resin was produced according to manufacturer's instructions. The experimental groups were further divided into two sub-groups, each reinforced with 2% or 5% MCC. Wax patterns were created by melting wax and pouring it into a stainless-steel mold cavity as shown in Figure 2. The wax patterns were then inserted into conventional denture flasks, enclosed with dental stone and a thin layer of petroleum jelly. The flask component was pressed using a hydraulic press. The flask was then placed in a wax removing machine (Acrydig) as shown in Figure 3.

A total of 30 samples were meticulously made (crafted), and then the specimens were sorted into three groups and coded appropriately based on groups/sub-groups. A digital scale (Sartorjus Junior) was used to measure the weights of both PMMA and MCC powders as shown in Figure 4 with an accuracy of 0.01 mg to create the experimental groups B and C. Table 1. shows the amounts of acrylic resin powder, liquid, and MCC which was used in this study.

Prior to the addition of the required amount of liquid monomer, the methyl methacrylate and MCC powders were carefully mixed to evenly scatter the MCC crystals (MMA) by using ball milling machine. Once the mixture had achieved the dough-like consistency, it was pressed down and loaded into the

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already prepared mold. Subsequently, the mixture was subjected to polymerization in a water bath for 6 h at 60 °C, followed by an additional one hour at 100 °C. After polymerization, the specimens were allowed to cool at room temperature on the bench. The specimens were then removed from the flask, as shown in Figure 5, and underwent a visual inspection for voids. Measurement was taken three times using a digital Vernier caliper. Subsequently, both groups' specimens were carefully finished and polished.

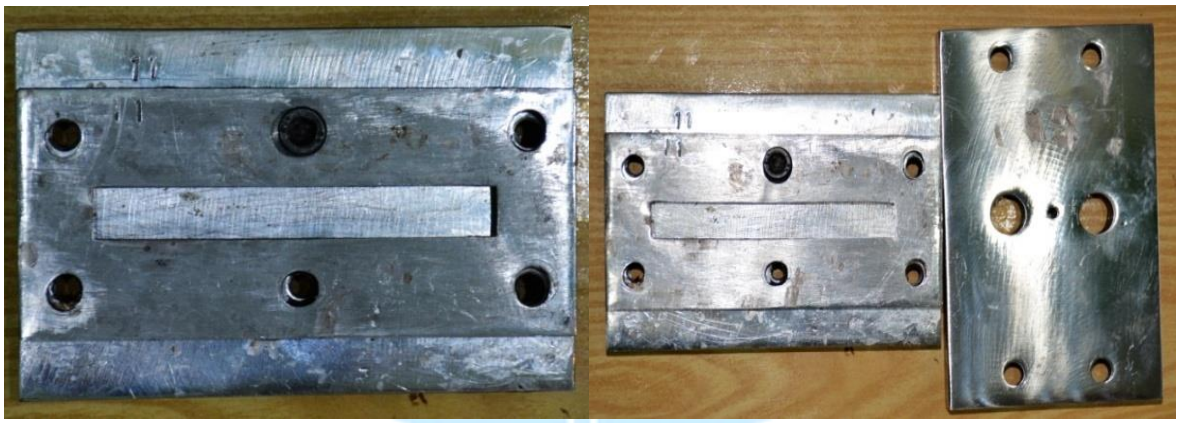

**Figure 1. Stainless-steel master mold prepared according to ISO 179A1:2005 specifications.**



**Figure 2. Wax patterns**

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**Figure 3. Acrydig (Manfredi®) polymerizing unit**



**Figure 4. Sartorius GL2241-1S scale 1100 ct**



**Figures 5. The specimens subjected to cooling on the bench at room temperature after polymerization.**

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ISSN: (e) 3007-1607 (p) 3007-1593

**Table 1.** Test groups and their mass composition

| S# | Groups | Powder (g)% | Liquid (ml)% | MCC (g)% |
|---|---|---|---|---|
| **A** | Conventional heat polymerized PMMA | 12.00 | 4.00 | Nil |
| **B** | Conventional PMMA reinforcement with 2% microcrystalline cellulose | 11.76 | 4.00 | 0.24 |
| **C** | Conventional PMMA reinforcement with 5% microcrystalline cellulose | 11.40 | 4.00 | 0.60 |

### 1.2 Experimental Conditions

The specimens from each group (n=10) were then divided in half, with one portion (n=5) underwent thermocycling for 5000 cycles at 5 °C and 55 °C with a dwell time of 30 sec on each cycle. The other half of each group (n = 5) were immersed in water for 48 h. All specimens were individually labelled before the impact testing phase.

#### 1.2.1 Thermocycling

For thermocycling, two stainless-steel water baths were utilized, both filled with deionized water. The hot water bath was maintained at 55°C (±2°C) using a digital thermostat, While the cold water bath's temperature was maintained at 5°C (±2°C) by adding ice. The specimens designated for thermocycling underwent a rigorous 5000-cycles process, with each cycle involving immersion in the water bath for 30 sec as shown in Figure 6.




**Figures 6. Two stainless steel water baths, at temperature of 55°C (±2°C) and 5°C (±2°C) with digital thermostat.**

### 1.3 Impact strength test

A Zwick pendulum impact tester was employed to perform the Charpy V-notch impact test (I.S). Prior to the IS test, the prepared specimens were incubated at 37 °C for 24 h. Each specimen, under the notch, possessed a width (bn) of 9.75 mm, a specification stipulated by ISO 179A1:2005. The construction of these specimens, utilizing a V-notch with dimensions of 0.25 mm length, 0.05 mm radius, 45±1 angle notch sensitivity (rn), notched bar impact strength, and support with a 62 mm ± 0.5 span. I.S. represents the amount of kinetic energy lost by the pendulum when the specimen is broken/fractured at the notch.

The specimens were placed in a simple supported beam and hammered at the contact point of the pendulum and on the side opposite to the notch in the middle in the same plane as the notch. Eq. (1) was employed to compute the impact strength (IS) of the specimens:

$$\mathrm{IS} = \frac{E}{bn \times d} \times 10^3$$

Where *bn* is the specimen width in millimeters, *d* is the specimen thickness in millimeters, and *E* is the amount of energy used by the sample when the Impact Resistance (J) is high (mm).

### 1.4 Materials

The materials used in this study are shown in Figure 7 and their specifications are described in Table 2.

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Figure 7. MCC, PMMA and Wax sheet.

**Table 2.** Details of the material used in this research their trade name, chemistry and manufacturer

| S. # | Trade name | Chemistry | Manufacturer |
|---|---|---|---|
| 1 | Heat cure acrylic resin (Mead Way) | Poly Methylmethacrylate (PMMA) (Powder) Methylmethacrylate (MMA) (Liquid) | MR. Dental Supplies Ltd. UK. Engropolymer and Chemicals Ltd. Pakistan. Local supplier: Peshawar Dental Supply, Peshawar |
| 2 | MCC | Microcrystalline cellulose (MCC) | JRS Pharma, HewetenR 102, Weissenborn, Germany |
| 3 | Stone plaster | $CaSO_4.\alpha 1/2.H_2O$ | China (Mainland) Local supplier: Peshawar Dental Supply, Peshawar |
| 4 | Modeling wax | N.A. | China (Mainland) Local supplier: Shah Dental Supply, Peshawar |
| 5 | Hydraulic press | N.A. | Universal Dental (Pvt.) Ltd. Local supplier: Shah Dental Supply, Peshawar |
| 6 | Custom prepared denture flasks for fabricating acrylic specimens | N.A | Universal Dental (Pvt.) Ltd. Local supplier: Shah Dental Supply, Peshawar |
| 7 | Cold mold seal | Sodium Alginate Liquid | IvoclarVivadent Corporate Pakistan Local supplier: Peshawar Dental Supply, Peshawar |

N.A. Not applied

### 1.5 Statistical Analysis

The impact strength means ± standard deviation was computed using the SPSS statistical software package v.26.0. One-way analysis of variance (ANOVA) ($P \leq 0.05$) and the POST HOC Test was used to see whether there are any statistically significant differences between the experimental groups.

## 2. Results

### 2.1 Impact strength before thermocycling

The results of the one-way ANOVA test are shown in the Table 3. The addition of MCC to acrylic denture base resin significantly increased its impact strength, as evidenced by a one-way ANOVA that demonstrated a significant difference in impact strength proportional to the amount of added cellulose ($P=0.00$). When comparing commercially available acrylic denture base resin to those groups with MCC reinforcement in various concentrations (2% and 5%), the impact strength is noticeably increased with the addition of 2% MCC. Table 4 shows that the impact strength of the 2% cellulose reinforced group B was higher than the control group A. The impact strength of group C, 5% cellulose, was much lower than that of groups A and B as the MCC amount increased.

The graph in Figure 8, indicates that the Impact strength increased when 2% of MCC was added. The best Impact strength was reached at 5.9670 $kJ/m^2$, which was more than 4.58236 $kJ/m^2$ higher than the control samples (group A).

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**Table 3.** Impact strength of the specimens before thermocycling

| Groups | No. | Mean (kJ/m$^2$) | S.D. | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound | | |
| A | 5 | 4.3067338E0 | 0.22198645 | 4.0311012 | 4.5823664 | 3.93562 | 4.49548 |
| B | 5 | 5.6422238E0 | 0.26160483 | 5.3173985 | 5.9670491 | 5.34126 | 5.93597 |
| C | 5 | 3.1436296E0 | 0.29507736 | 2.7772427 | 3.5100165 | 2.76258 | 3.55900 |
| Total | 15 | 4.3641957E0 | 1.08401830 | 3.7638864 | 4.9645051 | 2.76258 | 5.93597 |

ANOVA

| Impact Strength | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| Between Groups | 33.471 | 5 | 6.694 | 115.489 | 0.000 |
| Within Groups | 1.391 | 24 | .058 | | |
| Total | 34.862 | 29 | | | |

df= degrees of freedom; F = variation between sample means / variation within the samples

**Table 4.** Multiple comparisons of the mean Impact strength of the specimens before thermocycling

| Tests | (I) Group | (J) Group | Mean (kJ/m$^2$) Difference (I-J) | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Tukey HSD | A | B | -1.33549000 | .000 | -1.776331 | -.8946481 |
| | | C | 1.16310420* | .000 | .7222623 | 1.6039461 |
| | B | A | 1.33549000* | .000 | .8946481 | 1.7763319 |
| | | C | 2.49859420* | .000 | 2.0577523 | 2.9394361 |
| | C | A | -1.16310420 | .000 | -1.603946 | -.7222623 |
| | | B | -2.49859420 | .000 | -2.939436 | -2.0577523 |
| Scheffe | A | B | -1.33549000 | .000 | -1.796113 | -.8748665 |
| | | C | 1.16310420* | .000 | .7024807 | 1.6237277 |
| | B | A | 1.33549000* | .000 | .8748665 | 1.7961135 |
| | | C | 2.49859420* | .000 | 2.0379707 | 2.9592177 |
| | C | A | -1.16310420 | .000 | -1.623727 | -.7024807 |
| | | B | -2.49859420 | .000 | -2.959217 | -2.0379707 |

*. The mean difference is significant at the 0.05 level.

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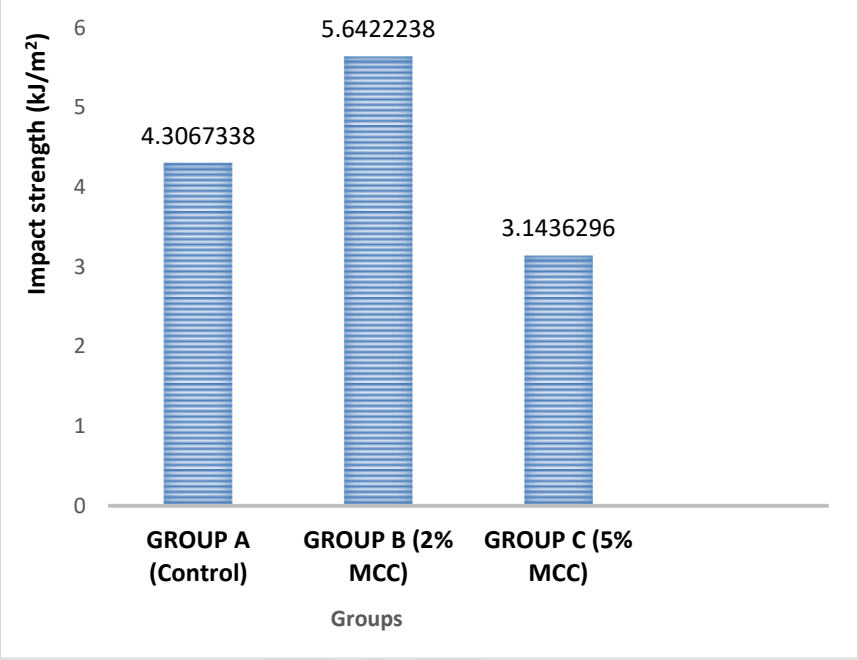


**Figure 8. Impact strength of the specimens before thermocycling**

**2.2 Impact strength after thermocycling**

The effects of loading and stress over time on the impact strength behavior of five specimens from each group were tested using thermocycling. As indicated in Table 5, the ANOVA test revealed a significant difference in impact strength between the MCC-added groups and the control groups (P=0.000). The impact strength of all test groups, with and without reinforcement, showed that the groups containing 2 % MCC had significantly increase impact strengths than the controls (group A1).

Furthermore, Scheffe's test procedure was employed to assess and show differences between the means of study variables among groups for Impact strength after thermocycling, and the results are summarized in Table 6. The impact strength of the 2% MCC group B1 is much higher than that of the control groups.

When a smaller amount of MCC was reinforced, the impact strength increased, as seen in Figure 9. With the ideal amount of 2% MCC (group B), the best Impact strength was achieved at 6.4898 kJ/m$^2$, which is more than 5.745 kJ/m$^2$ more than the control samples (group A1).

**Table 5.** Impact strength of the specimens after thermocycling

| Groups | N | Mean (kJ/m$^2$) | Std. Deviation | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound | | |
| A1 | 5 | 5.4932700E0 | .18700910 | 5.2610675 | 5.7254725 | 5.31082 | **5.74574** |
| B1 | 5 | 6.3123064E0 | .14296295 | 6.1347944 | **6.4898184** | 6.14358 | 6.47519 |
| C1 | 5 | 4.2940628E0 | .29595525 | 3.9265858 | 4.6615398 | 3.93984 | 4.65155 |
| Total | 15 | 5.3665464E0 | .88138328 | 4.8784526 | 5.8546402 | 3.93984 | 6.47519 |

**Table 6.** Multiple comparisons of mean Impact strength of the specimens afterthermocycling

| Test | (I) Group | (J) Group | Mean Difference (I-J) | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |

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| | | | | | | |
|---|---|---|---|---|---|---|
| **Tukey HSD** | A1 | B1 | -.81903640* | .000 | -1.1874210 | -.4506518 |
| | | C1 | 1.19920720* | .000 | .8308226 | 1.5675918 |
| | B1 | A1 | .81903640* | .000 | .4506518 | 1.1874210 |
| | | C1 | 2.01824360* | .000 | 1.6498590 | 2.3866282 |
| | C1 | A1 | -1.19920720* | .000 | -1.5675918 | -.8308226 |
| | | B1 | -2.01824360* | .000 | -2.3866282 | -1.6498590 |
| **Scheffe** | A1 | B1 | -.81903640* | .000 | -1.2039514 | -.4341214 |
| | | C1 | 1.19920720* | .000 | .8142922 | 1.5841222 |
| | B1 | A1 | .81903640* | .000 | .4341214 | 1.2039514 |
| | | C1 | 2.01824360* | .000 | 1.6333286 | 2.4031586 |
| | C1 | A1 | -1.19920720* | .000 | -1.5841222 | -.8142922 |
| | | B1 | -2.01824360* | .000 | -2.4031586 | -1.6333286 |

*. The mean difference is significant at the 0.05 level.

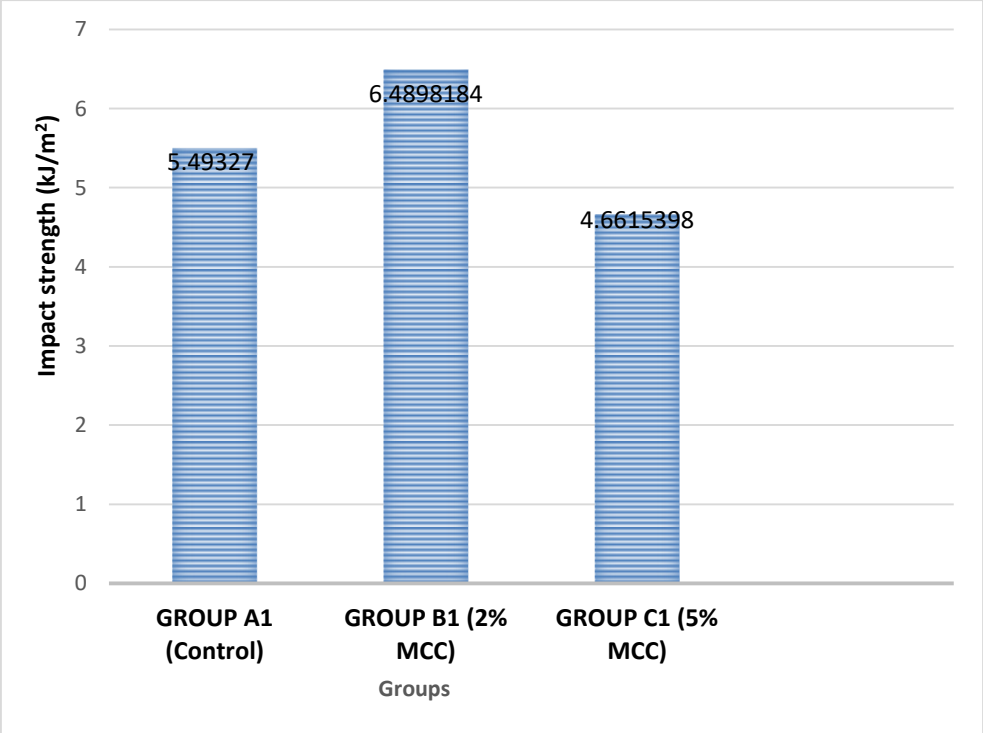


**Figure 9. Impact strength of the specimens After thermocycling**

**2.3 Comparison of Impact strength between all groups before and after thermocycling**

As can be seen in Figure 10, all the groups (A, B, and C) showed a considerable increase in impact strength after thermocycling (A1, B1, C1). When all of the groups were compared, 2% MCC reinforced Group B1 (after thermocycling) had the greatest impact strength. 5% MCC reinforced Group C (before thermocycling) had the lowest impact strength when compared to the other groups. The impact strength

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ISSN: (e) 3007-1607 (p) 3007-1593

of control group was 4.3067338 kJ/m$^2$ before thermocycling compared to after thermocycling which was 5.4932700 kJ/m$^2$, the impact strength was increased after thermocycling.

When compared to the control group, the 2% MCC reinforced group shows increased impact strength before and after thermocycling. The mean ± Std. Deviation impact strength before and After Thermocycling are shown in Tables 7 and Multiple Comparisons of mean of impact strength Before and After Thermocycling, Tukey HSD and Scheffe are shown in Table 8, the 5% MCC reinforced group shows a decrease in impact strength.

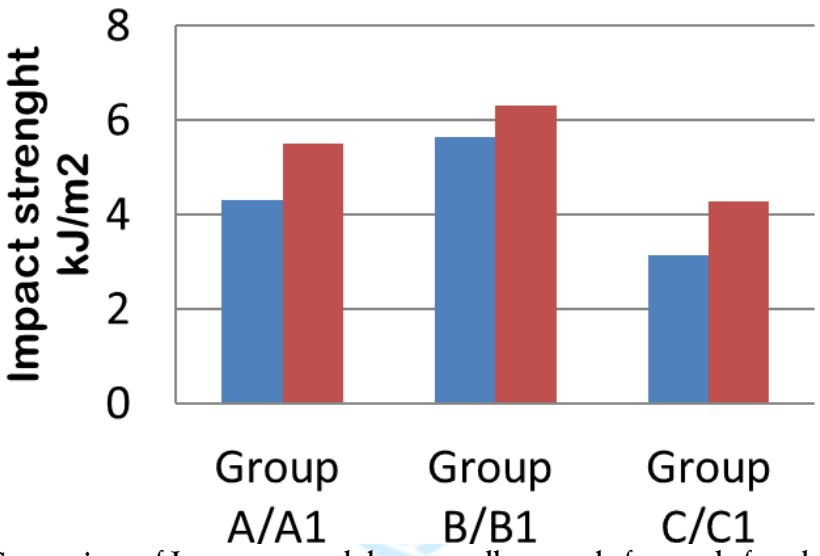


**Figure 10. Comparison of Impact strength between all groups before and after thermocycling**

**Table 7.** Mean impact strength before and After Thermocycling

| Groups | N | Mean (kJ/m2) | Std. Deviation | 95% Confidence Interval for Mean | | Minimum | Maximum |
|---|---|---|---|---|---|---|---|
| | | | | Lower Bound | Upper Bound | | |
| **Before Thermocycling** | | | | | | | |
| A | 5 | 4.3067338 | .22198645 | 4.031101 | 4.582366 | 3.93562 | 4.49548 |
| B | 5 | 5.6422238 | .26160483 | 5.317398 | 5.967049 | 5.34126 | 5.93597 |
| C | 5 | 3.1436296 | .29507736 | 2.777242 | 3.510016 | 2.76258 | 3.55900 |
| **After thermocycling** | | | | | | | |
| A1 | 5 | 5.4932700 | .18700910 | 5.261067 | 5.725472 | 5.31082 | 5.74574 |
| B1 | 5 | 6.3123064 | .14296295 | 6.134794 | 6.489818 | 6.14358 | 6.47519 |
| C1 | 5 | 4.2940628 | .29595525 | 3.926585 | 4.661539 | 3.93984 | 4.65155 |
| **Total** | 30 | 4.8653711 | 1.0964260 | 4.455958 | 5.274783 | 2.76258 | 6.47519 |

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**Table 8.** Multiple Comparisons of mean of impact strength Before and After Thermocycling

| Tests | (I) Group | (J) Group | Mean Difference (I-J) | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| Tukey HSD | A | B | -1.33549000* | .000 | -1.8062941 | -.8646859 |
| | | C | 1.16310420* | .000 | .6923001 | 1.6339083 |
| | | A1 | -1.18653620* | .000 | -1.6573403 | -.7157321 |
| | | B1 | -2.00557260* | .000 | -2.4763767 | -1.5347685 |
| | | C1 | .01267100 | 1.00 | -.4581331 | .4834751 |
| | B | A | 1.33549000* | .000 | .8646859 | 1.8062941 |
| | | C | 2.49859420* | .000 | 2.0277901 | 2.9693983 |
| | | A1 | .14895380 | .920 | -.3218503 | .6197579 |
| | | B1 | -.67008260* | .002 | -1.1408867 | -.1992785 |
| | | C1 | 1.34816100* | .000 | .8773569 | 1.8189651 |
| | C | A | -1.16310420* | .000 | -1.6339083 | -.6923001 |
| | | B | -2.49859420* | .000 | -2.9693983 | -2.0277901 |
| | | A1 | -2.34964040* | .000 | -2.8204445 | -1.8788363 |
| | | B1 | -3.16867680* | .000 | -3.6394809 | -2.6978727 |
| | | C1 | -1.15043320* | .000 | -1.6212373 | -.6796291 |
| | A1 | A | 1.18653620* | .000 | .7157321 | 1.6573403 |
| | | B | -.14895380 | .920 | -.6197579 | .3218503 |
| | | C | 2.34964040* | .000 | 1.8788363 | 2.8204445 |
| | | B1 | -.81903640* | .000 | -1.2898405 | -.3482323 |
| | | C1 | 1.19920720* | .000 | .7284031 | 1.6700113 |
| | B1 | A | 2.00557260* | .000 | 1.5347685 | 2.4763767 |
| | | B | .67008260* | .002 | .1992785 | 1.1408867 |
| | | C | 3.16867680* | .000 | 2.6978727 | 3.6394809 |
| | | A1 | .81903640* | .000 | .3482323 | 1.2898405 |
| | | C1 | 2.01824360* | .000 | 1.5474395 | 2.4890477 |
| | C1 | A | -.01267100 | 1.00 | -.4834751 | .4581331 |
| | | B | -1.34816100* | .000 | -1.8189651 | -.8773569 |
| | | C | 1.15043320* | .000 | .6796291 | 1.6212373 |
| | | A1 | -1.19920720* | .000 | -1.6700113 | -.7284031 |
| | | B1 | -2.01824360* | .000 | -2.4890477 | -1.5474395 |
| Scheffe | | | | | | |
| | A | B | -1.33549000* | .000 | -1.8866787 | -.7843013 |
| | | C | 1.16310420* | .000 | .6119155 | 1.7142929 |
| | | A1 | -1.18653620* | .000 | -1.7377249 | -.6353475 |
| | | B1 | -2.00557260* | .000 | -2.5567613 | -1.4543839 |
| | | C1 | .01267100 | 1.00 | -.5385177 | .5638597 |
| | B | A | 1.33549000* | .000 | .7843013 | 1.8866787 |
| | | C | 2.49859420* | .000 | 1.9474055 | 3.0497829 |
| | | A1 | .14895380 | .963 | -.4022349 | .7001425 |
| | | B1 | -.67008260* | .010 | -1.2212713 | -.1188939 |
| | | C1 | 1.34816100* | .000 | .7969723 | 1.8993497 |
| | C | A | -1.16310420* | .000 | -1.7142929 | -.6119155 |
| | | B | -2.49859420* | .000 | -3.0497829 | -1.9474055 |

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| | A1 | -2.34964040* | .000 | -2.9008291 | -1.7984517 |
| | B1 | -3.16867680* | .000 | -3.7198655 | -2.6174881 |
| | C1 | -1.15043320* | .000 | -1.7016219 | -.5992445 |
| A1 | A | 1.18653620* | .000 | .6353475 | 1.7377249 |
| | B | -.14895380 | .963 | -.7001425 | .4022349 |
| | C | 2.34964040* | .000 | 1.7984517 | 2.9008291 |
| | B1 | -.81903640* | .001 | -1.3702251 | -.2678477 |
| | C1 | 1.19920720* | .000 | .6480185 | 1.7503959 |
| B1 | A | 2.00557260* | .000 | 1.4543839 | 2.5567613 |
| | B | .67008260* | .010 | .1188939 | 1.2212713 |
| | C | 3.16867680* | .000 | 2.6174881 | 3.7198655 |
| | A1 | .81903640* | .001 | .2678477 | 1.3702251 |
| | C1 | 2.01824360* | .000 | 1.4670549 | 2.5694323 |
| C1 | A | -.01267100 | 1.00 | -.5638597 | .5385177 |
| | B | -1.34816100* | .000 | -1.8993497 | -.7969723 |
| | C | 1.15043320* | .000 | .5992445 | 1.7016219 |
| | A1 | -1.19920720* | .000 | -1.7503959 | -.6480185 |
| | B1 | -2.01824360* | .000 | -2.5694323 | -1.4670549 |

*. The mean difference is significant at the 0.05 level.

## 3. Discussion

According to the literature study, numerous investigations into denture base reinforcement employing various additives, such as fibers, nanoparticles, or chemical modification to improve mechanical performance have been reported. When creating conventional removable dentures for patients who are edentulous, polymethylmethacrylate resin is the material of choice in clinical settings (Paranhos et al., 2013, Soygun et al., 2013). Because of its ease of processing, equipment uses, cost effectiveness, and shade similarity to oral tissues, this material is used in prosthetic dental practice (Goldstein et al., 2012). Consequently, the acrylic denture base has a moderate mechanical quality (Mowade et al., 2012), and numerous studies identify fatigue failure as the main factor contributing to denture fracture or failure (Darbar et al., 1994, Jagger et al., 1999). The denture base is frequently subjected to a range of pressures from both inside and outside the oral cavity, such as biting effects, temperature variations, regular contact with water, saliva and food, and the potential for a rapid impact from a fall, which could cause denture failure or fracture. A denture fracture will cause disruption and discomfort for the patient, as well as functional and aesthetic problems, extra expenses, and time spent on denture repair or replacement.

Numerous studies on denture base reinforcements show an improvement in strength but do not result in clinical application. One factor contributing to this is the challenge of accurately putting the reinforcement material in the desired place during the manufacture of acrylic resin (Silikas et al., 2005). In earlier studies, strengthening denture base resin with aramid or carbon fibers had a negative cosmetic impact (Vallittu, 1996).

According to current developments in material science and engineering, green composites (polymers and filler particles sourced from renewable, natural sources) are the materials of the future. Improvements in several mechanical properties of those polymers, such as tensile and flexural strengths, are linked to the use of MCC as green fillers in some polymeric composites (Thakur et al., 2014, Van Krevelen et al., 2009, Wambua et al., 2003).

The current study was to create and enhance the mechanical characteristics of the heat cured PMMA denture base by examining the impact of adding reinforcement made of MCC fibers. Since cellulosic materials are significantly more rigid than polymer matrix, they increase the composites stiffness (Lee et al., 2014). In addition, MCC has a higher specific

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surface region than other traditional fibers cellulose, which is advantageous.

The amount of MCC in each part of the test specimen is likely that it causes the discrepancies between the two sets of reinforcements. In comparison to test specimens with 5% MCC, those with 2% MCC have lower MCC. The Impact strength of PMMA reinforced with 2% MCC before thermocycling was increased, which was higher than the impact strength of unreinforced PMMA. The impact strength of 5% MCC before thermocycling was less than unreinforced PMMA.

Excessive fiber concentration, according to several research, does not always increase the mechanical qualities of composites (Bentur et al., 2006). The results of the present study revealed a considerable improvement in mechanical qualities when a smaller amount of MCC (2%) was added to the conventional resin. The study by Mubarak et al., 2019, which found that the addition of more MCC reduces the impact strength, can also be used to explain this finding.

Despite adding reinforcement fibers, which can be difficult, we discovered in the current investigation that MCC was easily and uniformly introduced to the PMMA and that there were no issues with in the event of damage, dislocation during processing, or fracture, fibers protrusion. As opposed to the study (Rahaman et al., 2020), MCC powder was mixed with PMMA powder and liquid, and it demonstrated the typical course of construction of no rise in the mixture's viscosity as the acrylic denture progressed toward the dough stage.

Another notable finding was that adding MCC powder to strengthen the denture base did not produce any undesirable effect. Because PMMA denture base material favorably influences MCC mechanical characteristics and helps in minimizing fracture propagation, MCC is an excellent material to utilize as reinforcement in transparent polymeric matrix (Abuzar et al., 2010). But using fiber in the highly viscous denture base resin impregnable denture base polymer consisting of a blend of PMMA powder and MMA powder imposes some particular conditions (Abuzar et al., 2010). Because of the structural and anisotropy characteristics of the additional fiber from the denture polymeric matrix, the majority of the fiber reinforcing techniques previously stated suffer from some significant restrictions (Kiziltas et al., 2014).

The samples continuous phase after MCC addition had a homogeneous look free of any voids, and there was no granular structure. Most likely, the effective mixing of the formulation components during the preparation process caused the observed uniform distribution of MCC in the PMMA matrix (Vallittu, 1996). The microstructure analysis of the shattered sides of the samples revealed that the MCC particles were evenly distributed throughout the resin. The filler and the PMMA resin matrix did not have any gaps (clefts) between them. This observation might point to the existence of a link between the cellulose and resin, which might withstand the applied pressures and give acrylic base dentures reinforced with MCC a long lifespan (Elshereksi et al., 2009; Yu et al., 2012; Yu et al., 2014).

The results showed that test groups containing the 2% MCC significantly increased the impact strengths of the conventional PMMA. Similar research (Elshereksi et al., 2009; Kiziltas et al., 2014; Pöllänen et al., 2013) have provided support for these findings, showing that MCC strong mechanical properties play a significant role in enhancing mechanical qualities when combined with other polymers.

An impact test determines a sample capacity to survive a sudden shock. The impact strength reduces as cellulose content increases in the acrylic denture base, which is consistent with the findings of our investigation and is corroborated by Tajeddin et al. (2009). The impact strength also drops as cellulose concentration in the composite increases in the unnotched sample. In comparison to low density polyethylene, cellulose biocomposites have lower values of impact strength. Impact strength is calculated as the product of the energy needed to fracture the sample and its thickness. Since the sample thickness is nearly constant throughout all treatments, less energy is needed as the cellulose content in the biocomposite increases (Tajeddin et al., 2009). The current results seem to be in line with those of Yang et al., 2007), who claimed that the impact strength of composites (Rice husk flour incorporated Polypropylene) both notched and unnotched declined as filler loading increased but

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ISSN: (e) 3007-1607 (p) 3007-1593

dramatically rose with the addition of the compatibilizing agent.

According to research by Asar et al., 2013, the addition of 2% aluminium oxide boosted the impact strength of heat cured acrylic resin (Al2O3). As demonstrated by Salman et al., 2015, the addition of zirconia oxide (ZrO2) nanofiller at a concentration of 2% enhanced the impact strength of heat cured acrylic resin. Further studies by Salman et al., 2017 showed that adding 2% silica oxide nanoparticles also boosted the impact strength of heat cured acrylic resin. Similar to results of above studies, the results of this study also show that by adding 2 % MCC increased the impact strength of acrylic resin before and after thermocycling.

Compared to fibers, MCC has a bigger surface region for connecting with the framework. Furthermore, as noted in the literature, strengthening by filler reinforcement is based on the idea that a relatively soft ductile matrix is completely capable of transmitting a load to filler particles (Fonseca et al., 2016).

The findings of this study are consistent with research on other composite materials conducted in the past (Pollanen et al., 2013), demonstrating that the MCC has high surface area and modulus in addition to its stiffness, can help to improve the mechanical properties of PMMA.

## Conclusions

The results of the study conclude that all groups show considerable increase in impact strength after thermocycling. The impact strength of 2% cellulose reinforced group was higher than the control group before and after thermocycling. The impact strength of 5% cellulose was lower than other groups, as the MCC amount was increased, the impact strength was decreased before and after thermocycling.

## Recommendations

Although the objectives of this study were achieved but there are still some issues that require more research. Testing has been done with MCC additions of 2% and 5%. Therefore, more research is advised to establish the optimum MCC concentration that could strengthen PMMA. Future studies should look into other mechanical parameters like hardness, tensile strength, and compressive strength in light of the intended mechanical properties. Based on the results of the cytotoxicity test, an in vivo investigation of the MCC reinforced PMMA is strongly advised.

## Conflict of Interest

The authors declare no conflict of interest

## Acknowledgements

We are thankful to Peshawar Medical and Dental College, Peshawar, and Khyber College of Dentistry, Peshawar, for the technical support. We are thankful to Dr. Arshad Islam, Assistant Professor and Consultant, Department of Pathology, Medical Teaching Institution Lady Reading Hospital, Peshawar, Pakistan for his technical support and manuscript drafting and revision.

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