

# Effect of storage temperature and material shelf life on provisional crown's hardness and flexural strength: an experimental laboratory study

Laila Nur Azizah<sup>1</sup>   
Sekar Nirmala Dewi<sup>1</sup>   
Ika Andryas<sup>2\*</sup>   
Siti Wahyuni<sup>2</sup> 

<sup>1</sup>Study Program of Dentistry,  
Faculty of Dentistry Universitas  
Sumatera Utara, Indonesia  
<sup>2</sup>Department of Prosthodontic,  
Faculty of Dentistry Universitas  
Sumatera Utara, Medan, Indonesia

\*Correspondence  
Email | [ika.andryas@usu.ac.id](mailto:ika.andryas@usu.ac.id)

Submisi | 08 February 2026  
Revisi | 19 March 2026  
Penerimaan | 2 April 2026  
Publikasi Online | 31 April 2026  
DOI: [10.24198/jkg.v38i1.60076](https://doi.org/10.24198/jkg.v38i1.60076)

p-ISSN [0854-6002](https://doi.org/10.24198/jkg.v38i1.60076)  
e-ISSN [2549-6514](https://doi.org/10.24198/jkg.v38i1.60076)

Citation | Azizah LN, Dewi SN,  
Andryas I, Wahyuni S. Effect of storage  
temperature and material shelf life on  
provisional crown's hardness and  
flexural strength: an experimental  
laboratory study. J. Kedokt. Gigi Univ.  
2026;38(1): 9-16.  
DOI: [10.24198/jkg.v38i1.60076](https://doi.org/10.24198/jkg.v38i1.60076)



Submitted to Jurnal Kedokteran Gigi Universitas  
Padjadjaran for possible open access publication  
under the terms and conditions of the Creative  
Commons Attribution (CC BY-NC 4.0) license  
(<https://creativecommons.org/licenses/by-nc/4.0/>)

## ABSTRACT

**Introduction:** Provisional crowns are interim restorations placed on prepared teeth until the definitive crown is completed. Fractures of provisional crowns and bridges often occur as a result of crack propagation due to inadequate mechanical properties. This study aimed to analyze the effect of storage temperature and material shelf life on the surface hardness and flexural strength of bis-acryl provisional crown materials. **Methods:** This study was an experimental laboratory study with a posttest-only control design. Five cartridges of bis-acryl provisional material (SmarTemp®, shade A2, USA) were divided into two groups. Thirty five disc-shaped (10 x 2 mm) and thirty five bar-shaped (2 x 2 x 25 mm) bis-acryl specimens were produced by layering bis-acryl composite in an aluminum mold. Surface hardness was measured using Vickers Hardness Tester (Shimadzu HMV®, Japan), and flexural strength was evaluated using three-point bending test (Tensilon AND RTF-1350®, Japan). Data were analyzed using one-way ANOVA followed by a post-hoc LSD test. **Result:** The highest surface hardness value was 31.20±0.91 and the highest flexural strength value was 62.32±0.75. Data analysis showed significant differences in surface hardness (p-value=0.001) and flexural strength (p-value=0.0001). **Conclusion:** Surface hardness and flexural strength were affected by storage temperature and material shelf life. Bis-acryl materials, whether recently produced or with 12 months remaining before expiration, are recommended to be stored at 5°C or room temperature (27°C), as they exhibit better surface hardness and flexural strength compared to those stored at 35°C.

## Keywords

provisional crown, flexural strength, shelf life, hardness, temperature

## *Pengaruh temperatur dan masa penyimpanan terhadap kekerasan permukaan dan kekuatan fleksural bahan mahkota sementara: studi eksperimental laboratoris*

## ABSTRAK

**Pendahuluan:** Mahkota sementara merupakan restorasi sementara yang dipasang pada gigi yang telah dipreparasi sampai mahkota definitif selesai. Mahkota dan jembatan sementara sering terjadi retakan karena sifat mekanik material yang tidak adekuat. Penelitian dilakukan untuk menganalisis pengaruh temperatur penyimpanan dan masa penyimpanan bahan terhadap kekerasan permukaan dan kekuatan fleksural bahan mahkota sementara bis-acryl. **Metode:** Penelitian ini adalah studi eksperimental laboratoris dengan desain posttest only control design. Lima kartrid bahan restorasi sementara bis-acryl (SmarTemp®, shade A2, USA) dibagi menjadi 2 kelompok. Tiga puluh lima sampel berbentuk silindris (10 x 2 mm) dan 35 sampel berbentuk balok (2x2x25 mm) dibuat dengan cara memasukkan bahan bis-acryl ke dalam cetakan aluminium. Kekerasan permukaan diukur menggunakan Vickers Hardness Tester (Shimadzu HMV®, Jepang) dan kekuatan fleksural diuji menggunakan uji three-point bending (Tensilon AND RTF-1350®, Jepang). Hasil dianalisis menggunakan uji ANOVA satu arah yang dilanjutkan dengan uji LSD post-hoc. **Hasil:** Nilai rata-rata tertinggi kekerasan permukaan yaitu 31.20±0.91 dan kekuatan fleksural yaitu 62.32±0.75. Hasil analisis data menunjukkan adanya perbedaan signifikan pada kekerasan permukaan (p=0,001) dan kekuatan fleksural (p=0,0001). **Simpulan:** Kekerasan permukaan dan kekuatan fleksural dipengaruhi oleh temperatur dan masa penyimpanan produk. Bis-acryl yang baru diproduksi dan 12 bulan sebelum kadaluarsa disarankan disimpan pada suhu 5°C atau temperatur ruangan (27°C) karena memiliki kekerasan permukaan dan kekuatan fleksural yang lebih baik dibandingkan dengan bahan yang disimpan pada temperatur 35°C.

## Kata kunci

mahkota sementara, kekuatan fleksural, masa penyimpanan, kekerasan, temperatur

## INTRODUCTION

The provisional crown is an interim restoration placed on prepared teeth until the definitive crown is completed.<sup>1</sup> A provisional crown is needed to protect the pulp, maintain tooth position, restore function, aesthetics, and phonetics.<sup>2</sup> In addition, a provisional crown also serves to provide mechanical strength to support occlusal forces. Materials for provisional crowns must have ideal characteristics, including ease of manipulation and polishing, biocompatibility, strength, and abrasion resistance.<sup>1</sup> Surface hardness and flexural strength are essential parameters to a successful provisional treatment.<sup>3</sup> Provisional crown and bridge fractures often occur as a result of crack propagation caused by inadequate mechanical properties such as low surface hardness and flexural strength.<sup>4</sup>

Cracks in provisional crowns, especially the anterior region, can compromise the aesthetic aspect, whereas cracking in posterior provisional crowns interferes with masticatory function. Cracking in provisional crowns also increases the sensitivity of abutment teeth.<sup>5</sup> Stress concentration during functional and parafunctional activities (bruxism) often leads to fractures in a connector's area of a long-span bridge.<sup>6</sup> Minimal preparation of a tooth and voids formed during fabrication also will increase the risk of early restoration failure.<sup>4</sup> In complicated situations such as full mouth reconstruction, during the restorative phase of implant reconstructive procedure and crown lengthening, provisional crown and bridge ideally must accomplish several functions for the long duration of rehabilitation in the mouth (2 to 12 weeks).<sup>7,8</sup>

The decrease in surface hardness and flexural strength of provisional crowns is affected by temperature and shelf life.<sup>9</sup> The present study evaluated the mechanical properties of bis-acryl material 3, 12, and 21 months pre-expiration date according to actual and under accelerated storage conditions.<sup>10</sup> Shelf life is believed to affect the mechanical properties. A decrease in mechanical properties can occur in materials used for provisional crowns after exposure to moisture for a long time.<sup>11</sup> Shelf life can be affected by a variety of factors including temperature, humidity, and light.<sup>12</sup>

The storage temperature of provisional crown materials needs to be evaluated because it plays an important role in material stability. Thermal energy could promote mobility of the polymer chain, leading to the degradation and decomposition of the polymer.<sup>13</sup> Currently, allowing two-component composite resins to be stored at room temperature (27°C) without refrigeration (5°C) is well accepted.<sup>9</sup> Other studies store resin composites in refrigerators at 2–5 °C with the objective of extending their shelf life.<sup>14</sup> Because storage conditions for resin composites may vary according to geographical and climatic conditions (sun exposure and humidity) of the country.<sup>15</sup> Provisional materials generally have an expected shelf life 1 to 2 years from the date of manufacture when stored in proper condition.<sup>9</sup>

Several other studies suggested 35°C temperature as a recommended storage temperature to increase mechanical properties. Although this temperature has exceeded the manufacturer's recommendation, the literature suggests that there are benefits in raising the temperature of the composite before placement in increasing the flowability and adaptation of the material.<sup>15,16</sup> Moreover, several other studies also showed that these materials contain vulnerable initiators and other sensitive chemicals, which were prone to change material shelf life induced by temperature and storage time.<sup>9,15</sup>

The novelty of this study lies in the lack of available evidence evaluating the effect of shelf life at 21, 12, and 3 months prior to expiration under accelerated storage conditions. The first null hypothesis was that there was no effect of shelf life (Expiration date (E)-21 months, E-12 months and E-3 months) on surface hardness and flexural strength. The second null hypothesis was that there was no effect of storage temperature (5°C, 27°C, and 35°C) on surface hardness and flexural strength. This study aimed to analyze the effect of storage temperature and material shelf life on surface hardness and flexural strength of bis-acryl provisional crown materials.

## METHODS

This study was an experimental laboratory study with a posttest-only control group design. The sample preparation was divided into five groups to represent different material shelf lives and storage temperatures. Bis-acryl cartridges were placed at different storage temperatures to simulate variations in resin composite storage conditions due to sunlight exposure and humidity. The cartridges consisted of bis-acryl materials with 3 and 12 months remaining before the expiration date. The average shelf life of composite resin materials is approximately two years from the date of manufacture, and currently there is no ISO standard that provides specific guidelines for evaluating the shelf life of provisional crown materials.

In this study, a clinically practical approach was employed by selecting storage durations of two years, one year, and less than one year to represent long-term, mid-term, and short-term storage conditions, respectively.<sup>9</sup> Table 2 shows that the bis-acryl cartridges were placed in a refrigerator for 24 hours to achieve a storage temperature of 5°C, whereas other cartridges of bis-acryl with 3 and 12 months remaining before expiration date were also placed in an incubator for 24 hours to achieve a storage temperature of 35°C. Another cartridge of bis-acryl with 21 months pre-expiration date was placed at room temperature to achieve a storage temperature of 27°C. Each cartridge was divided into two groups of samples for surface hardness and flexural strength tests.

This research was conducted in April 2022 at the Research Center of the Prosthodontic Department, Faculty of Dentistry, Universitas Sumatera Utara. Table 1 shows the composition of bis-acryl for provisional restorations (SmarTemp®, shade A2, USA) used in this study, based on expiration date and identification of lot number to provide chemical stability testing on these materials.

**Table 1.** Composition of smartemp bis-acryl<sup>17</sup>

Chemical name	CAS No	Weight-%
Uncured methacrylate ester monomers	Proprietary	Proprietary
Silinated glass and silica fillers	Proprietary	Proprietary
Dibutyl phthalate	84-74-2	Proprietary
Benzoyl peroxide	94-36-0	Proprietary

The total number of samples in this study was 70 samples, including 35 specimens for the surface hardness test and 35 specimens for the flexural strength test. The minimum sample size was determined using the power sampling method, and the calculation showed that the minimum number of samples needed for each group was seven samples. Disc-shaped specimens (n=7) for the surface hardness test were fabricated in a mold measuring 10 mm x 2 mm, and bar-shaped specimens (n=7) for the flexural strength test were fabricated in a mold measuring 25 mm x 2 mm x 2 mm.<sup>9</sup>

The samples were produced by layering bis-acryl composite in a custom-made aluminum mold. For each specimen, the bis-acryl composite was placed in the mold, covered with a cellophane strip, and then gently pressed by a glass slide to flatten the surface and eliminate any voids while it polymerized. The specimens were removed from the molds, and the oxygen-inhibited layer was removed using alcohol. Then the specimens were placed in water for 24 hours at room temperature. All surfaces of the specimens were polished using abrasive paper with grit numbers #1000 and #1200 to standardize the specimen surfaces before measuring the surface hardness and flexural strength. Before testing, the length, width, and thickness of each specimen were measured by a caliper following standard procedures. Samples with surface porosity

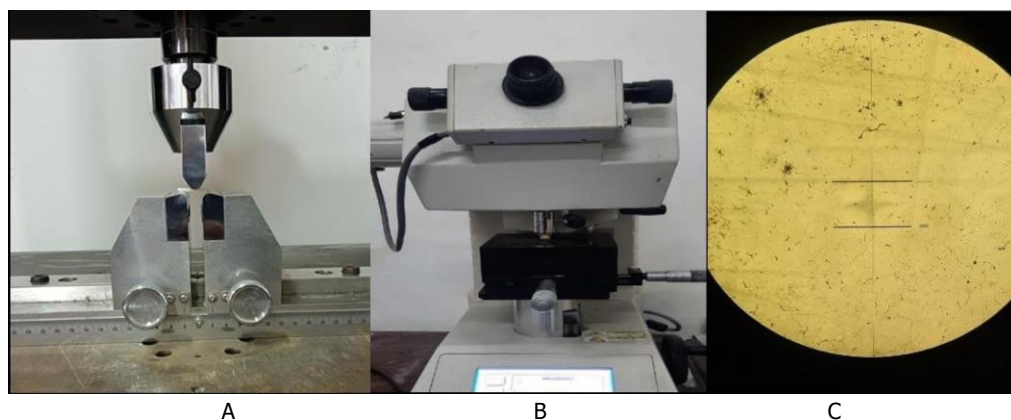
were excluded prior to the test because the results could be affected by surface porosity. These exclusions did not affect the final sample size, as replacements were prepared to maintain the required number in each group.

**Table 2.** Grouping of bis-acryl provisional crown material treatments based on expiration date and storage temperature

Group	Time to expiration	Temperature	Lot number
I	21 months before	27°C	2153521535
II	3 months before	5°C	2031220312
III	3 months before	35°C	2031220312
IV	12 months before	5°C	2167721677
V	12 months before	35°C	2153521535

Samples were assigned using a coded numbering system by a single operator with sequentially numbered containers. The first set was allocated to group I, the next to group II, until group V. All testing devices were calibrated prior to use in accordance with manufacturer guidelines to ensure measurement accuracy. Thirty-five specimens were prepared to identify the flexural strength. The test was done using a three-point bending test recommended by ISO 4049 with a Universal Testing Machine (Tensilon AND RTF-1350) at a crosshead speed 1 mm/min (Figure 1.A).<sup>17</sup> The maximum load at fracture was recorded and flexural strength was calculated by the formula  $FS = Pl/bh^2$ , where P represents the maximum measured load in N and beam geometry (width  $b$ , thickness  $h$  in mm), and  $l$  was the span width between 2 support bars ( $l = 20$  mm).

Another 35 specimens were prepared ( $n=7$ ) for surface hardness testing under the Vickers microhardness test (HMV Shimadzu, Japan). A 50 gf pressure was applied to the top of each specimen's surface for 15 seconds (Figure 1.B).<sup>2</sup> The diagonal curve was measured three times on three different surfaces arranged in such a way that each diagonal curve did not coincide or intersect, and then the mean value was taken (Figure 1.C). All groups used the same material (SmarTemp®, shade A2, USA), and all specimens were prepared, polished, and tested under standardized conditions. No methodological changes were applied after the trial study commenced.



**Figure 1.** A. Universal testing machine; B. Vickers hardness tester; C. Vickers indent on sample

The data were analyzed using Statistical Package for the Social Sciences (SPSS) version 20 (SPSS, IBM, Chicago, IL, USA). Testing for normality and homogeneity of variance was performed using the Saphiro-Wilk and Levene's tests, respectively. The mean and standard deviation values for microhardness and flexural strength were calculated for each group. Each group of microhardness and flexural strength values was analyzed using one-way analysis of variance (ANOVA) followed by the LSD post-hoc test with a 95% significance level for significant differences among the groups.

## RESULTS

The smallest mean value was found in the group containing material with 3 months remaining before the expiration date stored at 35°C (group III). The highest flexural strength mean was found in the group containing material with 21 months before the expiration date stored at 27°C (group I), followed by the group containing material with 12 months remaining before the expiration date stored at 5°C (group IV), the group containing material with 3 months remaining before the expiration date stored at 5°C (group II), and the group containing material with 12 months remaining before expiration date stored at 35°C (group V) (Table 3).

**Table 3.** One way ANOVA test results for surface hardness and flexural strength

Group	Surface hardness	p	Flexural strength	p
I	30.67±0.81	0.001*	62.32±0.75	0.0001*
II	29.67±0.97		54.78±0.49	
III	28.82±1.45		51.89±0.33	
IV	31.20±0.91		61.69±0.23	
V	29.01±1.18		58.80±0.23	

**Table 4.** Post-Hoc LSD test results for surface hardness and flexural strength

Group		Surface hardness	Flexural strength
I	II	0.097	0.0001*
	III	0.003*	0.0001*
	IV	0.369	0.552
	V	0.008*	0.0001*
II	III	0.152	0.0001*
	IV	0.013*	0.0001*
	V	0.267	0.0001*
III	IV	0.0001*	0.0001*
	V	0.738	0.0001*
IV	V	0.001*	0.0001*

\*Sig.: Statistical significance ( $p < 0.05$ )

The post-hoc LSD test was performed to determine the difference between each group. These results showed significant differences in surface hardness ( $p=0.001$ ) and in flexural strength ( $p=0.0001$ ) (Table 4). Bis-acryl stored at 5°C showed significantly higher flexural strength ( $p=0.0001$ ) compared to bis-acryl stored at 35°C. Thus, the material showed a significant decrease in flexural strength when the initial values (materials with 21 months remaining before the expiration date) were compared to all means of E-12m (material with 12 months remaining before the expiration date) and E-3m (material with 3 months remaining before the expiration date) ( $p=0.0001$ ). All these results indicated that the flexural strength of the bis-acryl composite was affected by shelf life and storage temperature with  $p=0.0001$  ( $p < 0.05$ ). No specific issues or adverse events were observed.

## DISCUSSION

Mechanical properties were affected by the distribution and density of filler particle shapes, type of monomers and their compositions, and degree of polymerization.<sup>15</sup> The degree of polymerization and the concentration of the cross-linked matrix had an impact on the resin material's characteristics. An increased degree of conversion and a higher concentration of cross-linked matrix resulted in a harder material.<sup>3</sup> The present provisional material was introduced using auto-polymerization. Auto-polymerizing composite resin is known to have a more unstable degree of polymerization than dual-

polymerizing composites. These materials still contain vulnerable initiators and other sensitive chemicals that are prone to degradation under certain storage conditions and have a limited shelf life.<sup>15,19</sup>

Clinicians might store restorative materials in refrigerators at 2-5°C to prolong the shelf-life and maintain the stability of restorative materials.<sup>20</sup> Some clinicians use composite materials after waiting for a while, but occasionally composite materials are used immediately after being removed from the refrigerator temperature. This variation in handling practices raises concerns regarding the optimal storage conditions and their impact on material properties.<sup>21</sup> Storing provisional crown materials at room temperature without refrigeration is also accepted and widely recommended. However, recent studies show that these materials may still contain unstable initiators that might affect the polymerization process.<sup>22</sup>

Based on the results of this study, bis-acryl stored at 5°C showed significantly higher surface hardness and flexural strength compared to bis-acryl stored at 35°C (Figure 2). These findings are consistent with the study conducted by Yuanxin et al, who reported that decreases in surface hardness and flexural strength were initiated by thermal energy capable of initiating polymer chain movement, leading to degradation.<sup>15</sup>

It was believed and investigated that at high temperatures, the breaking of these chemical bonds could happen, resulting in the formation of free radicals. The formed free radicals are extremely active and react with the surrounding molecules. Hence, further broken chains are triggered to generate more free radicals. Subsequently, many parameters of polymers would be changed, including molecular weight, and degree of conversion. As a result, the working performance, such as the mechanical performance of the polymers, would alter dramatically, thereby increasing the risk of material fracture.<sup>13</sup>

In the present study, bis-acryl stored at 27°C showed higher surface hardness and flexural strength compared to bis-acryl stored at 5°C and 35°C. This finding is similar to the research of Osternack et al, who reported that polymerization occurred more rapidly at room temperature compared to 5°C, leading to residual monomers being trapped between polymer chains, which hindered the development of a fully cross-linked polymer network.<sup>15,23</sup> Composite resin stored in a refrigerator would perform the "soft start polymerization method". Low-temperature storage is believed to reduce monomer mobility, decrease reaction speed, and prolong the pre-gel phase without decreasing the hardness value.<sup>24</sup> Manufacturers suggest storing their materials in a refrigerator to stabilize and delay decomposition, thereby prolonging material shelf life.<sup>9</sup>

Bis-acryl material showed a significant decrease in surface hardness and flexural strength when the initial values (materials with 21 months remaining before the expiration date) were compared to all means of E-12m (materials with 12 months remaining before the expiration date and E-3m (materials with 3 months remaining before the expiration date). Polymer-based provisional restorative materials would degrade over time.<sup>9</sup> Materials approaching the end of their shelf life experience a decrease in the activity of their constituent components, such as filler in the resin, where the filler becomes inert and the coupling agent is hydrolyzed, causing complete debonding.<sup>13</sup>

The bis-acryl resin in this study (SmartTemp®, USA) contains benzoyl peroxide as an initiator, which had a higher intrinsic risk of temperature-induced degeneration of properties over time.<sup>9</sup> An ineffective polymerization process, especially in the last months of the shelf life, gives rise to a reduced cross-link density and possibly higher concentrations of residual monomers and oligomers, thereby decreasing mechanical properties such as surface hardness and flexural strength.<sup>9,13</sup>

The clinical implications of the study emphasize the importance of carefully selecting storage temperature to maintain clinical performance and shelf life of provisional materials.<sup>25</sup> Patients often prioritize the aesthetics and functionality of provisional restorations, especially in complex occlusal reconstructions.<sup>26</sup> Inadequate mechanical

properties of provisional material are indicated by low surface hardness and flexural strength. Low surface hardness and low flexural strength under 50 MPa often lead to cracks in the provisional crown.<sup>2,4</sup> Cracking that occurs in the provisional crown, especially the anterior region, can disrupt aesthetics, while cracking in posterior provisional crowns interferes with masticatory function.<sup>27,28</sup>

The limitations of this study are related to its in vitro design, which may not fully represent provisional crowns or bridges under oral conditions.<sup>29,30</sup> Additionally, the polishing process of the provisional crown material may introduce variability. Although the polishing was performed using a rotary grinder, the thickness of the samples after polishing may vary, which could potentially influence the surface hardness and flexural strength measurements. Future studies should ensure that all samples are consistently prepared to the same thickness before polishing, and should use micrometers or other precision instruments to measure the thickness of each sample before and after polishing to ensure uniformity across all samples.

## CONCLUSION

Storage temperature and material shelf life variably affected the surface hardness and flexural strength of bis-acryl provisional crown materials. The implication of these findings is that recently produced bis-acryl materials or those with 12 months remaining before the expiration date are recommended to be stored at 5°C or room temperature (27°C) because they exhibit better surface hardness and flexural strength compared to materials stored at 35°C.

**Acknowledgment:** None.

**Author Contribution:** Conceptualization, A.I, W.S, A.N.L, dan D.N.S; methodology, A.I, W.S, A.N.L, dan D.N.S; software, A.N.L, dan D.N.S; validation, A.I, W.S, A.N.L, dan D.N.S; formal analysis, A.I, W.S, A.N.L, dan D.N.S; investigation, A.N.L, dan D.N.S; resources, A.I, W.S, A.N.L, dan D.N.S; data curation, A.I, W.S, A.N.L, dan D.N.S; writing-original draft preparation, A.I, W.S, A.N.L, dan D.N.S; writing-review and editing, A.I dan W.S.; visualization, A.N.L, dan D.N.S; supervision, A.I, dan W.S; project administration, A.N.L, dan D.N.S; funding acquisition, A.N.L, dan D.N.S. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding

**Ethical Approval:** This study was approved by the Health Research Ethics Committee of Universitas Sumatera Utara (protocol number 263/KEPK-USU/2022).

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** Not applicable.

**Conflict of Interest:** The authors declare no conflict of interest.

## REFERENCES

- Rosenstiel SF, Land MF, Fujitomo J. Contemporary fixed prosthodontics 5th ed., St.Louis: Mosby Inc.; 2016. p. 467-75.
- Binalrimal SR, Yaman P, Dennison JB, Jin Q. Flexural strength evaluation of immediate and aged repair of provisional restorative materials. *J Dent Oral Health*. 2018;1(1):1-7.
- Digholkar D, Madhav NV, Palaskar J. Evaluation of the flexural strength and microhardness of provisional crown and bridge materials fabricated by different methods. *J Indian Prosthodont Soc*. 2016; 16:328-34. <https://doi.org/10.4103/0972-4052.191288>
- Rubio DA, Gaete AD, Arcis CB, Company JMM, Moscardo AP, Silla JMA. Mechanical properties of provisional dental materials: A systematic review and meta-analysis. *PLoS One*. 2018;13(2):1-19. <https://doi.org/10.1371/journal.pone.0193162>
- El Najjar G, Halal R, Daou M, Zebouni E. In vitro evaluation of the flexural strength of different temporary crown materials, after thermocycling. *Acta Sci Dent Scienecs*. 2021;5(9):121-34. <https://doi.org/10.31080/ASDS.2021.05.1197>
- Jasim AH, Alwan LE, Abood AZ. Comparison of fracture resistance of cad/cam interim bridge and conventional interim resin bridge. *World J Ph armaceutical Res*. 2019;8(5): 262-275. <https://doi.org/10.20959/wjpr20195-14612>
- Alduroj V, Chajareenont P, Yavirach A, Angkasith P. Semi-permanent restorations just temporary or long-lasting use?: a review of the literature. *CM Dent J*. 2023;44(1):13-21. <https://doi.org/10.12982/CMDENTJ.2023.001>
- Katayama Y, Ohashi K, Iwasaki T, Kameyama Y, Wada Y, Miyake K, et al. A study on the characteristics of resin composites for provisional restorations. *Dent Mater J*. 2022;41(2):256-65. <https://doi.org/10.4012/dmj.2021-006>
- Niem T, Heun U, Hübner A, Wöstmann B. Effect of cartridge storage time and ambient laboratory conditions on the stability of mechanical properties of bis-acryl interim resin materials. *J Prosthodont*. 2021;1-9. <https://doi.org/10.1111/jopr.13338>

10. Calligaris S, Manzocco L, Anese M, Nicoli MC. Accelerated shelf life testing. *Food Quality and Shelf Life*. Elsevier Inc.; 2019. p. 359–92.
11. Puspitasari D, Prasetyo A, Rahman MD, Diana S, Nahzi MYI. Storage temperature effect on degree of polymerization and surface hardness of bulk-fill composite resin. *J Int Dent Med Res*. 2019;12(2):405-10.
12. Wajong KH, Damiyanti M, Irawan B. The Effect of shelf life on the compressive strength of resin modified glass ionomer cement. *J Physics*. 2017;1-6. <https://doi.org/10.1088/1742-6596/884/1/012101>
13. He Y, Li H, Xiao X, Zhao X. Polymer degradation: category, mechanism and development prospect. *E3S Web Conf* 2021;290: 01012.
14. Maksoud OA, Hamama HH, Wafaie RA, Wassefy N, Mahmoud SH. Effect of shelf-storage temperature on degree of conversion and microhardness of composite restorative materials. *BMC oral health*. 2023;23(57):1-9. <https://doi.org/10.1186/s12903-023-02770-0>
15. Sabbagh J, Nabbout F, Jabbour E, Leloup G. The effect of expiration date on mechanical properties of resin composites. *J Int Soc Prev Community Dent*. 2018;8(2):99–103. [https://doi.org/10.4103/jispcd.JISPCD\\_445\\_17](https://doi.org/10.4103/jispcd.JISPCD_445_17)
16. Sharafed din F, Motamedi M, Fattah Z. Effect of preheating and precooling on the flexural strength and modulus of elasticity of nanohybrid and silorane-based composite. *J Dent Shiraz Univ Med Sci*. 2015;16(3):224-29.
17. Parkell. "SmarTemp Crown & Bridge Material." Accessed April 28, 2026. <https://parkell.com/SmarTemp-Provisional-Material>
18. Rajput R, Hasti A, Choudhary A, Duggal S, Ali S. Comparative evaluation of flexural strength and surface roughness of three different commercially available provisional restorative material: an in-vitro study. *J Clin Diagnostic Res*. 2022;16(1):8-12. <https://doi.org/10.7860/JCDR/2022/51527.15830>
19. Saati K, Khansari S, Farnaz Mahdisiar, Valizadeh S. Evaluation of microhardness of two bulk-fill composite resins compared to a conventional composite resin on surface and in different depths. *J Dent Shiraz Univ Med Sci*. 2022;23(1):58–64. <https://doi.org/10.30476/DENTJODS.2021.87669.1278>
20. Takagi N, Ida Y, Iuchi T, et al. Effect of pre-polymerization temperature on the mechanical properties and viscosity of light-cure flowable composite resins for core build-up. *Dent material J* 2026; 45(1):105-11. <https://doi.org/10.4012/dmj.2025-193>
21. Abdelmaksoud OA, Hamdan HH, El-wasefy NA. The impact of storage temperature on the microhardness of composite restorative materials. *International J Dent Med Sci Res* 2022;4(2):403-5. <https://doi:10.35629/5252-0402403405>
22. El-Maksoud OA, Hamama H, Wafaie RA, et al. Effect of shelf-storage temperature on degree of conversion and microhardness of composite restorative materials. *BMC Oral Health* 2023; 23:1-9. <https://doi.org/10.1186/s12903-023-02770-0>
23. Osternack FHR, Caldas DB, Rached RN, et al. Impact of refrigeration on the surface hardness of hybrid and microfilled composite resins. *Braz Dent J* 2009;20(1):42-7. <https://doi: 10.1590/s0103-64402009000100007>
24. Alomozainy M. Influence of storage temperature on vickers microhardness of resin composite. *J Dentomaxillofacial Sci*. 2018;3(2):70. <https://doi.org/10.24105/aedj.2018.10.1>
25. Zain AO, Piva E, Pimentel H, et al. Impact of storage conditions on the fracture reliability and physical properties of dental resin-based composite. *Braz Oral Res* 2024;15:38. <https://doi: 10.1590/1807-3107bor-2024>
26. Alharti R, Alqahtani AR, Alshehri AM, et al. Effect of Thermal Aging on Color Stability and Mechanical Properties of High-Density CAD/CAM Polymers Utilized for Provisional Restorations. *J Funct Biomater* 2025; 16(6):223. <https://doi:10.3390/jfb16060223>
27. Allorerung J, Anindita PS, Gunawan PN. Uji kekerasan resin komposit aktivasi sinar dengan berbagai jarak penyinaran. *Jurnal e-GiGi*. 2015;3(2):444-8. <https://doi.org/10.35790/eq.3.2.2015.10010>
28. Mohamadullah. Clinical Evaluation of Factors Leading to Provisional Crown Failure. *Scholars Journal of Applied Medical Sciences* 2014;2(6):3504-9. <https://doi:10.36347/sjams.2014.v02i06.131>
29. Haralur SB, Albarqi AT, Alamodi AG, et al. Comparison of various surface treatment procedures on the roughness and susceptibility to staining of provisional prosthodontic materials. *J funct biomater* 2024;15:1-15. <https://doi: 10.3390/jfb15090256>.
30. Alageel O, Alhijji S, Alsadon O, et al. Trueness, flexural strength and surface properties of various three dimensional (3D) printed interim restorative materials after accelerated aging. *Polymers* 2023;15(14):3040. <https://doi.org/10.3390/polym15143040>