EFFECT OF GOLD NANOPARTICLES ADDITION ON ADAPTATION AND COLOR STABILITY OF COMPLETE DENTURE BASE MATERIAL: AN IN- VITRO STUDY

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Article History: Received: 26.06.2023 **Revised:**04.07.2023 **Accepted:** 22.07.2023

Abstract

Background: Poly methyl methacrylate (PMMA) is the dominant acrylic that is widely used to produce partial and complete dentures., and its application is often accompanied by the formation of biofilm. The mechanical properties of dentures have been developed by reinforcing with various agents like rubbers, fillers, and fibers. Progressively, novel dental materials reinforcement tactics have been developed following the advancement in Nano dentistry. The aim of this work was the preparation of PMMA/gold nanoparticles (AuNps) to improve the mechanical properties of heat -polymeried PMMA. In the present study, adaptation and color stability were investigated. Adaptation was measured using Euromex microscope and Color stability was evaluated using spectrophotometer.

Results: Adaptation of a PMMA/gold nanoparticles (AuNps) were decreased for all groups containing AuNps whatever Color stability of a PMMA/gold nanoparticles (AuNps) were increased for all groups containing AuNps Statistical analysis was performed by means of the SPSS 16 software package.

Conclusions: Incorporation of AuNps into heat- polymerized PMMA resin led to increase color stability and decrease adaptation of complete denture base material.

Keywords: PMMA, Gold nanoparticles (AuNps), Euromex microscope, Color stability, Denture base.

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DOI: 10.53555/ecb/2023.12.1044

1. Introduction

Complete dentures are the least expensive and invasive alternative for the rehabilitation of completely edentulous patients [1]. Fit and aesthetics of the dentures are one of the most important factors in the success of removable prostheses. More comfort and a lower risk of traumatic ulcers are provided by well fitted dentures [2]. A tissue-matching denture fit is essential to retain complete dentures effectively, which impacts phonetics and masticatory effectiveness [3]. Therefore, one of the main goals when constructing a complete denture should be achieving the best tissue fit [4].

The most commonly used material for construction of denture bases is polymethyl methacrylate (PMMA) resin because of its excellent mechanical properties, aesthetics, tissue compatibility, and simplicity [5]. One of the most drawbacks of PMMA resin as a denture base is its dimension inaccuracy as a result of polymerization shrinkage and expansion, water sorption, and internal stress release [6]. This change may impair denture retention and stability and result in poor denture-tissue adaptation [7].

As a result, the physical and mechanical properties of PMMA polymer have been enhanced by the inclusion of a wide variety of other components to its composition, including glass fibers, long carbon fibers, metal wires and nanoparticles [8].

Nanotechnology primarily refers to a broad field of pragmatic science and technology whose overarching concept is the regulation of matter at the atomic and molecular level. The study of materials at the nanoscale, or between 1 and 100 nm, is known as nanoscience. Polymer nanocomposite is the term used to describe a polymer that has nanoparticles dispersed within it [9].

The polymer nanocomposites' properties differ on the kind of integrated nanoparticles, namely their size, form, doses, and binding with the polymer matrix itself [10]. To integrate organic nanoparticles into PMMA in this context, numerous efforts have been made [11]. For example, PMMA/alumina nanocomposite was fabricated utilizing alumina nanoparticles coated with acryloxypropyl dimethyl methoxy silane with better mechanical properties than pure PMMA. To increase PMMA's resistance to abrasion, stearic acid altered CaCO3 nanoparticles were additionally included into the material [12]. To further enhance the radiopacity characteristics, BaSO4 nanoparticles were added to PMMA [13].

In the current study, gold nanoparticles (AuNps) were used. AuNps are a great choice as a filler in nanocomposites because they have desirable traits like stability, non-toxicity, homogenous particle size, and antibacterial properties. There are three common techniques to incorporate AuNps into a polymer: (1) adding nanoparticles to the polymer, (2) creating nanoparticles during polymerization, and (3) adding nanoparticles to the monomer [14-15].

There are several studies that discuss tissue adaptation of various denture base materials, but there is lack of information about the effect of AuNps incorporation to denture base polymers to it's tissue adaptation . According to Emera RMK et al., the mechanical properties, adaptation, and retention of alumina nanoparticles (Al2 O3 NPs) modified polyamide resin denture base materials were evaluated. [16, 17].

In this study adaptability and colour stability were the aspects that were studied. The most significant addition of the current research is a comparative evaluation of the impact of AuNps addition to PMMA polymer on the mechanical characteristics of acrylic resin that has been thermally polymerized [18, 19].

Recently, researchers have concentrated on using fillers with various sizes, shapes, orientations, and forms to strengthen the denture base resin. Since the development of nanotechnology, nanofillers are being utilized more frequently to improve the mechanical qualities of denture base resin. However, the mechanical qualities of the composite in the dental prosthesis are one of the most significant properties, during function. Therefore, the purpose of this work was to evaluate and investigate how one of the reinforcing agents as gold nanoparticles affect the mechanical characteristics of the heat cured PMMA denture base resin [20].

2. Materials and methods

I – Materials:-

Heat Cured acrylic Resin	Polymethylmethacrylate	Vertex. Holland *
Nano gold Heat Cured acrylic Resin	Polymethylmethacrylate with nano gold particles	Vertex. Holland**

* (vertex) Rapid heat polymerized conventional acrylic resin, The Netherlands.

** (vertex) Rapid heat polymerized conventional acrylic resin, The Netherlands.

➢ **Synthesis and characterization of AuNPs (gold nanoparticles)[21]:**

Gold nanoparticles have been prepared by chemical reduction method as reported by Turkevich. A solution of Chloroauric acid ($HAuCl_4$) has been used as gold ions (Au^{3+}) precursor. The sodium citrate has been used as reducing agent and Polyvinylpyrrolidone (PVP) with 40K Molecular weight as stabilizing agent. The color of the solution slowly turned into wine red color , indicating the reduction of the Au^{3+}ions to gold nanoparticles.

The suspension dried thermally at 80oC and crushed to get fine powder then, mixed physically with heat cured acrylic resin with ratio 0.05% w/w.

II – Methods

Eighteen identical waxed up maxillary complete dentures were constructed then divided into two equal groups: - Nine conventional heat-cured acrylic maxillary dentures Group (I) & Nine gold nanoparticles (AuNPs) modified heat cured acrylic resin maxillary dentures Group (II).

Denture Fabrication:

A silicone mold of a master edentulous maxillary cast with flawless alveolar ridge surfaces was used to create 18 identical maxillary stone castings. The molds were made using synthetic stone. An auto-polymerizing acrylic resin record foundation (thickness = 2 mm) was created on the master cast using a technique that has already been described. In the buccal sulcus of the cast, a 20 mm high occlusal wax rim was made, and it later shrunk to 10 mm in the region surrounding the second molar. Teeth from an acrylic resin denture are used to cover the mould. On the left side of the carved wax rim, there were canines, central and lateral incisors, as well as other anterior teeth.

The optimal tooth arrangements for complete dentures were created on two sheets of modelling wax that were specially made for the cast. Twenty sets of semi-anatomical teeth and twenty semi-anatomic teeth were used to create the optimal tooth configuration from the original cast on all of the casts.

Measuring the adaptation:

For the posterior palate border gap measurements, the denture base placed on the respective master cast was trimmed to a horizontal line 5-mm away from the posterior end using a vertical trimmer with a diamond disc under water cooling. The cut surfaces were polished using abrasive paper to allow a visual distinction **(Fig 1).**

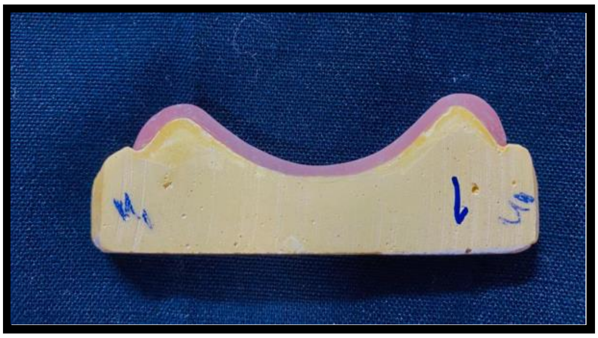


Figure (1) shows the cut surfaces of a horizontal line 5-mm away from the posterior end the denture base.

- Euromex microscope*was used to measure the maximum border gap (Pmax) at the posterior palatal midline and deepest vestibule **(Fig 2).**

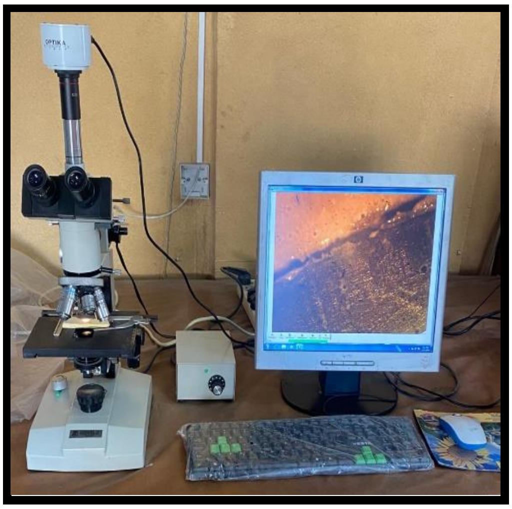
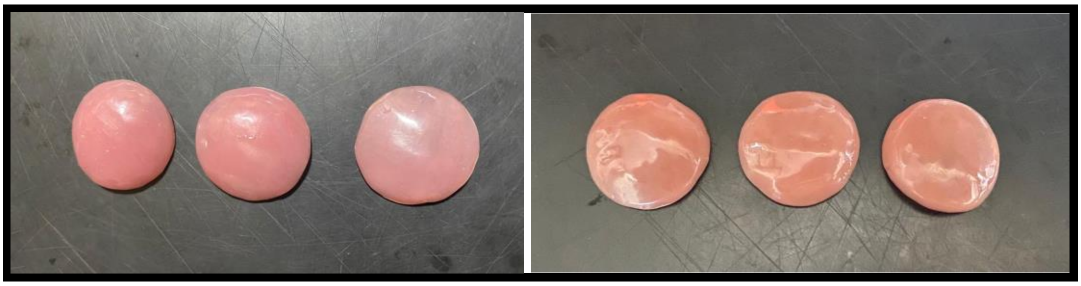


Figure (2) shows euromex microscope was used to measure the maximum border gap.

- Measuring the distance between the points on the tracing plates was done by euromex microscope, this device measure the distances in X, Y-axis.
- The measuring procedure repeated three times for each plate and the mean were calculated.
- The data were collected, tabulated, and statistically analysed.
- * Euromex microscope Holland.

Measuring color stability:

- After measuring the adaptation, the palatal portion of the denture was cut into a circle of 2.5 cm diameter according to the manufacturer's recommendation using a standard drill. These specimens were used in measuring colour stability **(Fig 3).**
- Different staining solutions (tea, coffee, and cola) were prepared for specimens to be immersed.
- All specimens were stored in distilled water at 37 c for 48 hours prior to testing.



A) Specimens of heat –cured acrylic resin . B) Specimens of gold nanoparticles (AuNPs) modified heat cured acrylic resin.

Figure (3) shows disc-shaped specimens.

Preparation of staining solutions [22]:

- The tea solution was prepared by immersing five tea bags into 800 ml of boiled water.
- To prepare the coffee solution, 16 g of coffee was poured into 800 ml of boiled distilled water.
- Both solutions were stirred every 15 minutes for 10 seconds until they cooled down to 37 C, and then filtered through a filter paper to remove any particulate residues.
- Each beverage solution was stirred once a day in order to reduce the precipitation of particles and replaced daily.

*(Lipton yellow label tea, unilever- London, UK).
**(Nescafe Classic, Nestle- Istanbul, Turkey).
* (Coca cola, Coca cola Company, USA).

- Before pouring the solutions into cups, each group contains 10 coded specimens with a small round bur on their periphery from away area of color measuring.
- The solutions were cooled to room temperature before the specimens were immersed completely in cups of beverages.
- For carefully avoiding specimen-to-specimen contact within the staining solution, each specimen was stored individually in a cup of 25 ml of the tested solution. To prevent fungal growth, the solutions were changed every day.
- The specimens of each group were stored in each solution at 37◦C in a dark environment to simulate intraoral conditions for 30, 60 and 90 days.
- The specimen of each group was exposed to three beverages per day that divided into four cycles (periods). Each cycle is about 6 hours of exposure (2 hours in tea , 2 hours in coffee and 2 hours in cola .
- After each beverage of exposure, specimens were washed for 1 min and then stored in distilled water at 37◦C.
- After immersion of each specimen into all beverages used in this study, the specimens were washed under distilled water and dried before measuring the color on 30, 60 and 90 days of immersion **.**
- The color stability testing was performed by using of spectrophotometer (**Fig.4)** Color measurement of the specimens from each denture base material was recorded at four periods, one before immersion at beverages as a base color and on 30, 60 and 90 days of immersion.

Figure (4) shows Agilent Cary 5000 spectrophotometer with software device..

- The specimens were washed under distilled water and dried before measuring the color. The specimens were placed in the center of the measuring head of a spectrophotometer with the aid of a silicone putty **.**
- Prior to measurement taking, the spectrophotometer was calibrated according to the manufacturer's instructions by using the supplied white calibration standard. Three measurements were taken at a time from one point, which corresponded to the central region of the labial surface of each tooth. The average.
- Value of these three readings was automatically calculated by the spectrophotometer and recorded.

Color measurement software*:

- This software calculates color indices from the spectra given by the spectrophotometer.
- Color measurement was assessed for each specimen using the CIE- L* a* b*- color space system.

* Cary UV Workstation software, Sponsored by Agilent Technologies, 2022.

Color calculation:

Color changes were characterized using the Commission Internationale d'Eclairage L*a*b* color space (CIE L*a*b*).

The average of the colorimetric measurement of the specimens which immersed in the same solution were from each type were taken before the immersion.

The average of the colorimetric measurement of the specimens, which immersed in the same solution were taken after the immersion.

Data Analysis

The collected data were obtained through in-vitro case-control study on randomly selected samples according to selected eligibility criteria. Data were statistically analyzed by Microsoft Excel ® 2016[1], Statistical Package for Social Science (SPSS)® Ver. 24[2]. and Minitab[3] ® statistical software Ver. 16. Data were revealed as means and standard deviations for further analysis using paired t-test to evaluate effect of processing on different dimensions of complete denture. In addition, Student`s t test performed to evaluate significance comparison between both groups.

Results:

Using Student`s t-test for significance evaluation of independent variables, it was revealed that there was significant difference between both groups as P-value < 0.05, as listed in table (1) and showed in figure (5).

Table (1): Descriptive and Comparative Statistics of Posterior Palate Border Gap Measurement:

	N	Group (I)		Group (II)		P-value
		MD	SD	MD	SD	
Left Crestal	9	0.11	0.012	0.27	0.023	**0.0001***
Right Crestal	9	0.18	0.017	0.21	0.017	**0.0018***
Mid Palatal	9	0.32	0.22	0.34	0.22	**0.8495 (ns)**

N; Number, MD; Mean Difference, SD; Standard Deviation, P; Probability Level
***significant Difference**
Ns; insignificant Difference.

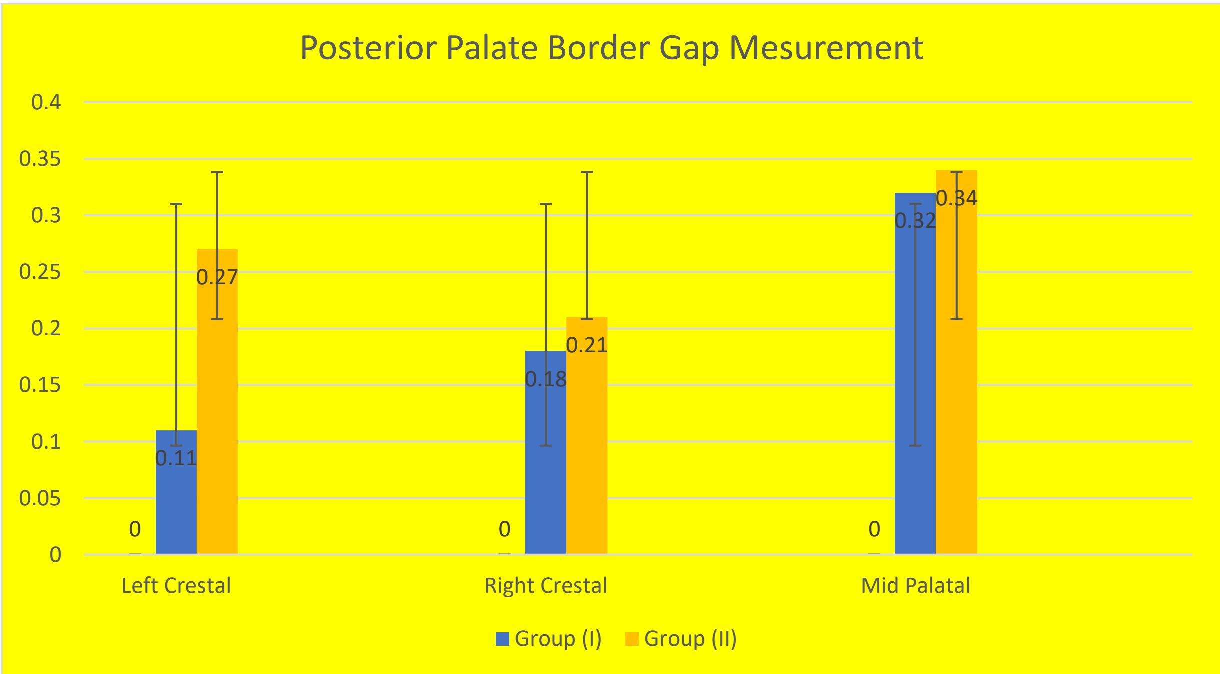


Figure (5): Bar Chart revealing Descriptive and Comparative Statistics of Posterior palate Border Gap Measurement .

[1] Microsoft Cooperation, USA.
[2] IBM Product, USA.
[3] Minitab LLC, USA.

II- Color Stability Measurement (ΔE):
Using student`s t-test for significance evaluation of independent variables, it was revealed that there was high significant difference between both groups as P-value < 0.001 at different follow up periods, as listed in table (2) and showed in figure (6).

Table (2): Descriptive and Comparative Statistics of Color Stability Measurement (ΔE):

	Group (I)		Group (II)		P-value
	M	**SD**	**M**	**SD**	
After 30 Days	5.77	.16	4.44	.16	**0.0001***
After 60 Days	9.22	1.19	5.34	.66	**0.0001***
After 90 Days	12.24	1.39	10.24	1.60	**0.012***

N; Number, M; Mean, SD; Standard Deviation, P; Probability Level
***Significant Difference**

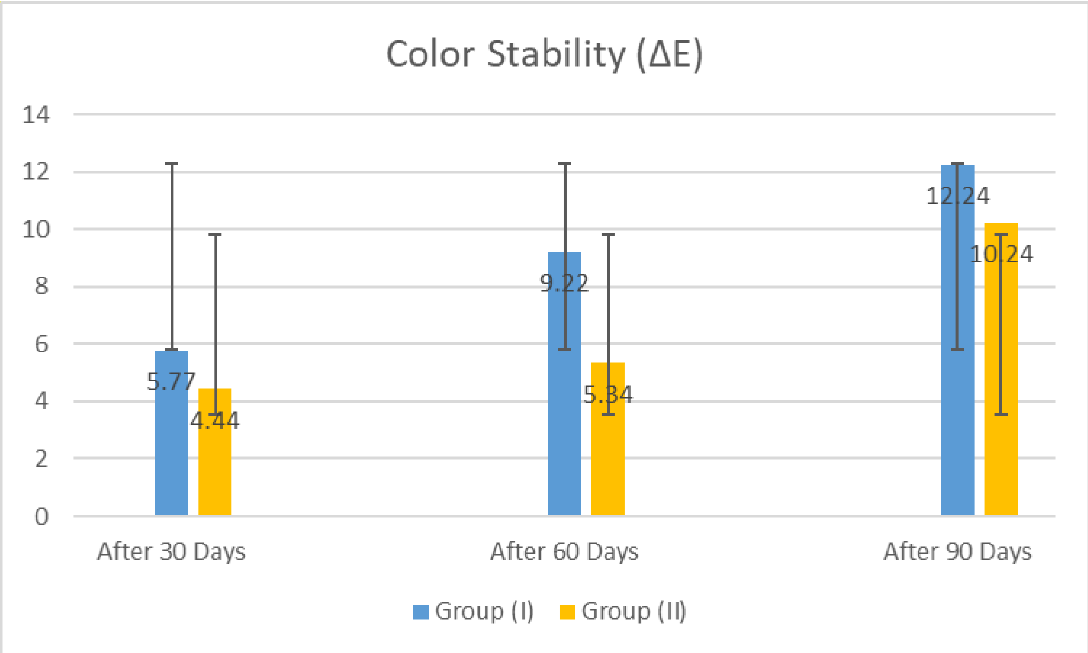


Figure (6): Bar Chart revealing Descriptive and Comparative Statistics of Color Stability Measurement (ΔE)

DISCUSSION

The aim of this study was to ascertain how the addition of gold nanoparticles to conventional acrylic resin materials influenced the materials' color stability and adaptation. However, adding Au particles to any sort of material may boost its qualities while increasing its costs. Biocompatible materials are required when using denture bases in clinical settings to prevent the release of hazardous chemicals and hypersensitivity reactions since they come into close contact with the oral mucosa. The size of the AuNp particles used in this study was 10 and 20 nm for group 2, which is consistent with a study that found that gold nanoparticles with a size of 1-2 nm had very harmful effects, although numerous studies have indicated that AuNPs with a size range of 10–20 nm do not have any adverse effects [23].

Studies investigating the effects of different nanoparticles on the mechanical properties of acrylic resin have shown contradictory results. However, none of the previous studies examined how gold nanoparticles impact PMMA's mechanical properties, making it hard to compare the results of this study to those of earlier, comparable studies [24].

According to Asghari Sana et al., the strength of nanoparticles decreases with increasing nanoparticle concentrations, with the integration of nanoparticles like Ag, TiO_2, and SiO_2 having an impact on the mechanical properties of acrylic resins. According to their findings, this study employed gold nanoparticles with a modest concentration (0.05%). According to the study, PMMA flexural strength decreased when AuNP concentrations were higher (0.2%) than when they were lower (0.05%). Therefore, it is plausible to infer that, in clinical practice, adding AuNPs to PMMA at the optimum concentrations may

enhance the mechanical qualities of denture bases [25–26].
The results of this study demonstrated that, at the right and left crestal areas, posterior palatal border gap formation (degree of adaptation) was greatest in nano-particle reinforced heat-cured acrylic denture base resins and least in conventional heat-cured acrylic denture base resins. However, using traditional heat-cured acrylic resin bases, the mid-palatal area was where gaps were most likely to emerge. This difference may be caused by the need for more packing pressure in the nano-particle reinforced heat-cured acrylic denture base resins than in the conventional heat-cured acrylic denture base resins due to the addition of additional fillers to the matrix of PMMA, while the changes in the mid-palatal region are consistent with numerous studies that show that dimensional stability is important in denture fabrication [27].

In the current study, a comparison of the color stability of conventional heat-cured acrylic denture base resins and those reinforced with gold nanoparticles revealed that the former had the greatest discoloration, with an E value of 12.24 (P 0.05), while the latter had the least discoloration, with an E value of 10.24 (P 0.05). A combination of factors, including different optical characteristics and the presence of noble inert metal, may be to blame for this variation in color stability [28].

The findings of this study are in agreement with those of Ghosh SK, Nath S, who said that gold nanoparticles (GNPs) have attracted a great deal of interest from researchers in recent years due to their exceptional physicochemical features. This discrepancy may be explained by the fact that gold is one of the most stable elements known to man, as well as by the fact that Mie's Theory may be used to explain the surface plasmon polaritons, a photophysical phenomenon connected to the high optical characteristics of gold nanoparticles. In a nutshell, Mie proposed that the color of colloidal gold nanoparticles resulted from light scattering and absorption on the surface of nanosized particles, which caused color surface reflection on the surface of gold nanoparticles reinforced heat-cured acrylic denture base resins [29].

5. Conclusion

Within the limitations based on the results of this *in vitro* study, it could be concluded that:
1. Conventional heat cured acrylic resin denture bases showed the most accurate adaptation of the denture base than gold nanoparticles (AuNPs) modified heat cured acrylic resin with concentration 0.05%.
2. Gold nanoparticles (AuNPs) modified heat cured acrylic resin with concentration 0.05% showed better color stability than conventional heat cured acrylic resin denture base material.

More research should be done on many kinds of the material because the current study only examines in vitro scenarios and one brand of heat-polymerized PMMA. Following that, work on biocompatibility and antimicrobial properties is proceeding as expected, with clinical studies being the ultimate goal.

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