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Evaluation of the thermal conductivity of polymethacrylic with additives of various metals

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The effect of additives of gold, silver, aluminum and copper nanoparticles on the thermal conductivity of polymethacrylic (base) was studied. The concentration of added nanoparticles was 0.25%. weight. The addition of silver significantly increased thermal conductivity, followed by copper, gold and finally aluminum. The thermal conductivity values of polymethacrylic are 0.28 W/μ. and 0.25 W/μ when adding gold and aluminum, respectively. The properties of polymethacrylic did not change significantly when adding the same amount of silver.
Keywords: Combining metal with polymethacrylate, thermal conductivity, acrylic resin, metallic nanofiller

Оцінка теплопровідності поліметакрилу з добавками різних металів. *Ayad Jyad Jarjis, Atyaf S. Al Rawas, Mohammad Mahmood Uonis*
Вивчено вплив добавок наночастинок золота, срібла, алюмінію та міді на теплопровідність поліметакрилу (основи). Концентрація доданих наночастинок становила 0,25%. вага. Додавання срібла значно збільшило теплопровідність, за ним прямували мідь, золото та, нарешті, алюміній. Значення теплопровідності поліметакрилу становлять 0,28 Вт/мк. та 0,25 Вт/мк при додаванні золота та алюмінію, відповідно. Властивості поліметакрилу при додаванні тієї ж кількості срібла суттєво не змінилися.

1. Introduction :

The thermal transfer coefficient measures the efficiency with which a gas or liquid transfers energy across its surface, therefore discharging energy from its surface, and is dependent on a number of variables, including the specific heat, density, and heat transfer coefficient of the medium to which heat is passed[1]. In order to determine the heat transfer coefficient, the temperature difference between the two objects must be known[2][3]. The heat transfer coefficient is not regarded as a qualitative property of a material, but rather as a function of the surrounding medium, its flow velocity v, and the kind of flow [4][5].

Acrylic is a transparent plastic substance with good adhesion to adhesives, is easy to manufacture, and has robust qualities when compared to many other transparent polymers[6][7]. Dental acrylic resin comes in three varieties: those that require heat, those that cure on their own, and those that cure with light[8]. Conventional denture bases are made of acrylic polymers heated to a specific temperature[9]. Denture bases made of hot polymerized acrylic resin are still often used because of the material's many benefits, such as its low water absorption, low cost, simplicity of manufacture and repair without the need for laboratory personnel, and biocompatibility[10-13]. In con-

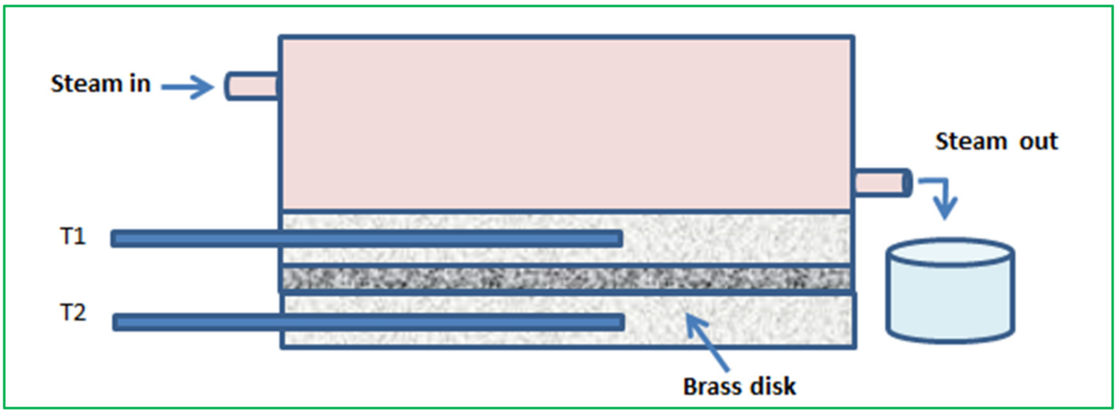

Figure 1. Schematic picture of the Lees disk

trast, the acrylic resin may prevent the patient from sensing the temperature of a beverage, leading to serious burns in the back of the neck or perhaps the entire oesophagus[13][14]. In the past few years, several changes have been made to the polymer to make it better and more useful. These changes have been made to improve its thermal properties, tear strength, and bonding. Several of these techniques included the use of nanoscale materials such as fiber filler[15], glass fiber [16], metal oxides[17,18], carbon fillers[19][20] and nanofillers [21][22]. To provide the best possible properties of polymer nanocomposites containing inorganic nanoparticles, it is essential to consider the nanoparticles' type, shape, size, concentration, and interaction with the polymer matrix[23] . Few attempts have been made to investigate the low thermal conductivity of acrylic resin. It's clear that more investigation is needed. The use of a denture base material with high thermal conductivity has been shown to improve patient satisfaction in the elderly and protect tissue. It also makes patients more comfortable with their dentures and enhances their sense of taste [24]. Despite these limitations, the acrylic resin can be modified by polymerizing conductive material particles into liquid or powder form. Silver can improve water absorption, thermal conductivity by thermal expansion coefficient, and polymerization shrinkage [25][26]. The use of alumina oxide ceramic improves thermal conductivity and durability while reducing polymerization shrinkage [27]. Advantages may become apparent when comparing the properties of a composite structure to those of one of its component materials [28].

Nanoparticles of different metals, such as gold, silver, and aluminium, have not been compared in any study with the aim of increasing the thermal conductivity of denture base material.The objective of the study is to add nanoparticles of high purity (99%) metals with good thermal conductivity that are safe for human consumption, such as gold, silver, aluminium, and copper, in a proportion of 25.0% to the acrylic material (the base) used to produce dentures. This is done because people who wear dentures take longer to feel the heat or cold of the foods and beverages they consume. This ratio was chosen to promote thermal conductivity, allowing the denture wearer to feel the heat of his food and drink as it entered his mouth. Mechanical properties were unaffected since the amount added was so small in relation to the acrylic (base) used to make the dentures.

2. Experimental approach

Lees discs were used to measure and determine thermal conductivity (Figure 1). The Lee disc consists of two individual components. The metal tube has a vent at the top, through which steam can escape. A copper or brass disc of the same diameter as the metal cylinder serves as the basis. These metals have known specific heat capacities. The preceding diagram depicts the placement of samples between two metal surfaces, with thermostats T1 and T2 placed over the appropriate positions. Steam is introduced and released through holes A and B. The upper thermometer should be checked at the same time as the lower one, once the lower one has stabilised at T2, for example, after 75 minutes of steam circulation.

When we placed the upper half of the device on top of the bottom disc, the lower disc's temperature increased by around 10 degrees Celsius above the θ 2 degrees seen in the first scenario. After removing the top disc, we stack the insulating disc over the metal disc to pre-

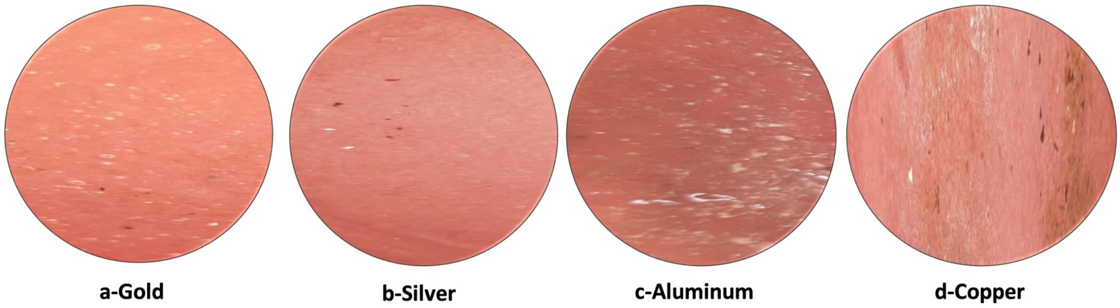

Figure 2. The microscope images of samples surfaces

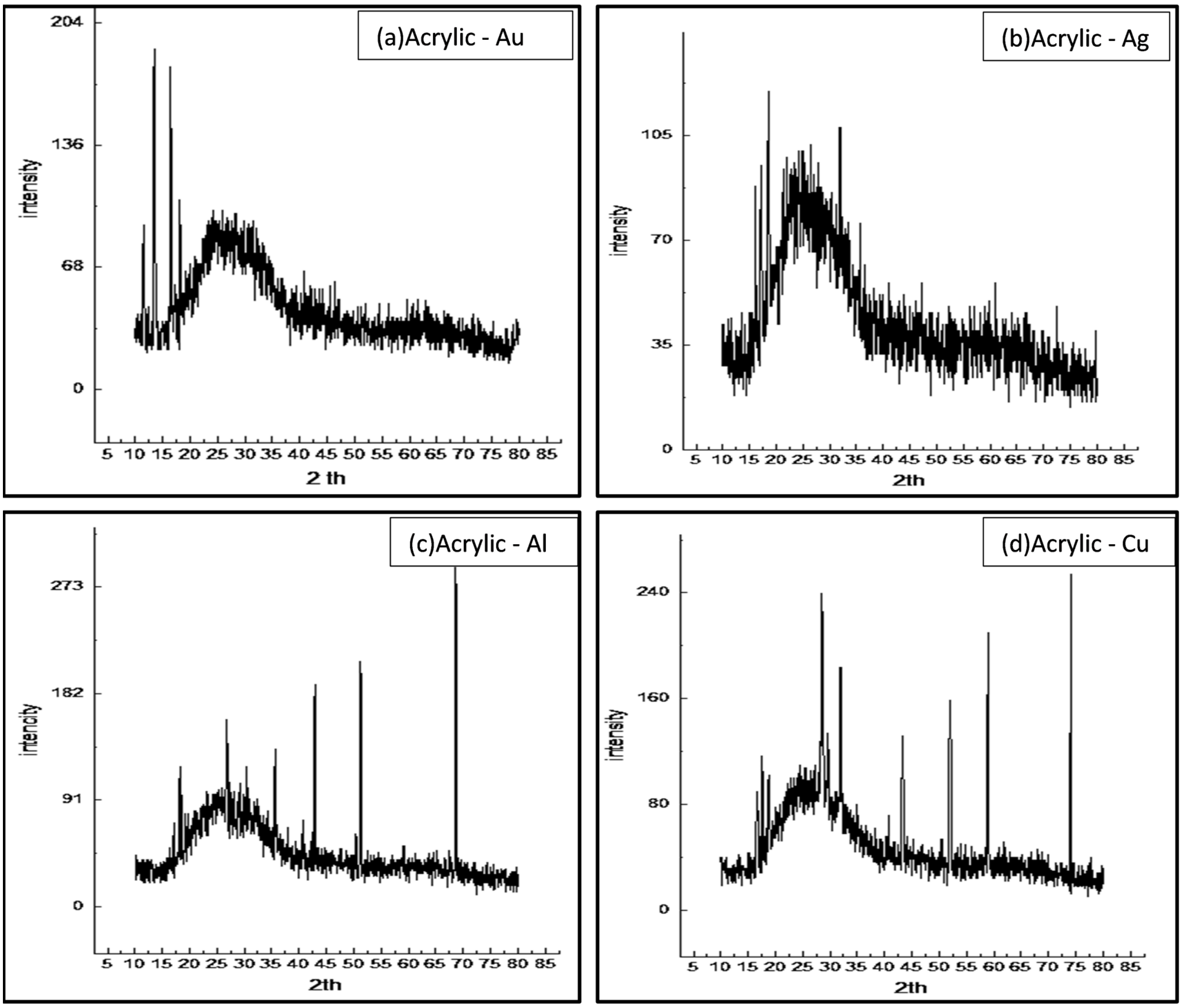

Figure 3. X-ray intensities with angle 2θ for acrylic material mixed with nanoparticles of (a) gold , (b) silver, (c) aluminum and (d) copper

vent electricity from leaking through. Note the progress minute by minute until the temperature on the stationary thermometer T2 drops to about 10 degrees Celsius below θ 2.

3. Results and Discussion

Samples of acrylic were made by fusing acrylic with 0.25 g of various nanoparticles materials (gold, silver, copper, and aluminium), as illustrated in Figure 2. The resulting samples were disc-shaped with dimensions of 2 mm thickness and 12.5 cm diameter.

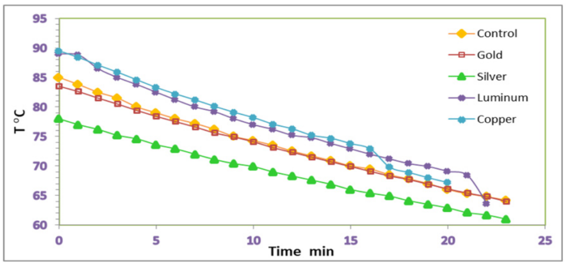

Figure 4. The decrease in temperature with time (cooling curves) for the samples studied

Table 1. Thermal conductivity of the metals studied

Material	Thermal conductivity (w/m k)
Silver	429
Copper	386
Gold	317
Aluminum	237

Figure 3 shows the x-ray spectra of the four elements with acrylic. It can be seen that the samples are amorphous with the presence of several peaks that belong to the acrylic, gold, silver, aluminum and copper. The peaks for gold nanoparticles with acrylics appears at 2θ between 11-70° [29] , while the peaks for silver with acrylic also appear between 15-75[30], aluminum nanoparticles peaks appear between 16-68° and finally the peaks due to copper nanoparticles appear between 16-74° [31].

The thermal conductivity was determined from cooling curves for all the materials studied (Figure 4). The thermal conductivity values of acrylic after mixing with all elements are shown in Table 1. The addition of silver will significantly increases thermal conductivity, because pure silver has the highest thermal conductivity coefficient (429w/m.k). The values for other metals are lower – (386 w/m.k.), (317w/m.k.) and (237 w/m.k.) for copper ,gold and aluminum nanoparticles respectively (Figure 5). Several possible explanations can be proposed, including lattice vibration and mobility convergence, particle size identity, and the similarity between gold and aluminium in their ability to impede thermal conductivity

It was discovered that the sample containing silver had the highest thermal conductivity value; hence, the next most important test was the compression test. This is because dentures are subjected to an incredible amount of pres-

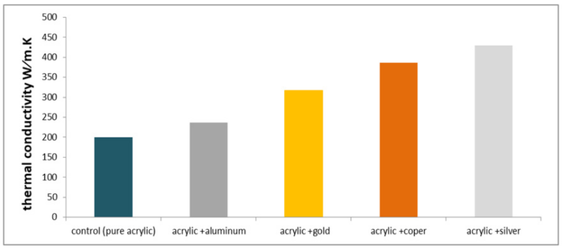

Figure 5. Thermal conductivity for pure acrylic (control) and all other mixtures

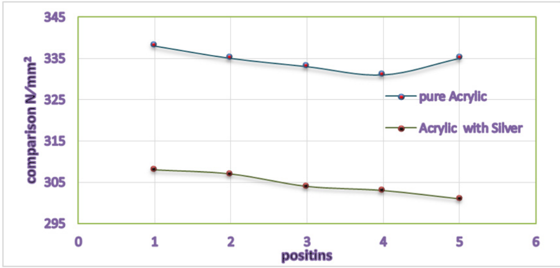

Figure 6. Regional compression at different positions on the samples surfaces for both pure acrylic and the mixture (acrylic with silver)

sure when cutting and chewing food due to the impact of the powerful jaw muscle. The compressibility test was performed at five position s on the sample , the test showed that adding a certain percentage of silver nanoparticles had no noticeable effect on the sample when compared to the pure acrylic sample ,this was illustrated by the comparison presented in Figure 6.

4. Conclusions

The mixtures were fabricated by combining acrylic with 0.25 g of different nanoparticle materials (gold, silver, copper, and aluminum). The maximum thermal conductivity was significantly enhanced by the addition of silver nanoparticles to acrylic in comparison to the other metals. The inclusion of this quantity of silver did not result in a discernible change to the material's inherent mechanical characteristics, where we found that the acrylic mixed with silver has a lower compressive value compared to pure acrylic.

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References

1. Moreira, T. A.; Colmanetti, A. R. A.; Tibirica, C. B. *Journal of the Brazilian Society of Mechanical Sciences and Engineering* **2019**, *41*, 1-25.
2. Panotopoulos, G. P.; Haidar, Z. S. *Dentistry Journal* **2022**, *10*, 43.
3. Niu, L.; Dong, S.-J.; Kong, T.-T.; Wang, R.; Zou, R.; Liu, Q.-D. *Plos one* **2016**, *11*, e0158233.
4. Lin, M.; Genin, G. M.; Xu, F.; Lu, T. *Applied mechanics reviews* **2014**, *66*.
5. Lin, M.; Luo, Z. Y.; Bai, B. F.; Xu, F.; Lu, T. J.: Fluid mechanics in dentinal microtubules provides mechanistic insights into the difference between hot and cold dental pain. *PloS one* **2011**, *6*, e18068.
6. Jaafar, M.*Malaysian Journal of Microscopy* **2018**, *14*.
7. Bettencourt, A. F.; Neves, C. B.; de Almeida, M. S.; Pinheiro, L. M.; e Oliveira, S. A.; Lopes, L. P.; Castro, M. F. *Dental materials* **2010**, *26*, e171-e180.
8. (8) Hassan, A. A.; Jameel, A.; Nahidh, M.; Hamid, D. *Journal of Stomatology* **2019**, *72*, 215-221.
9. Raszewski, Z.; Nowakowska-Toporowska, A.; Nowakowska, D.; Więckiewicz, W. *Mini Reviews in Medicinal Chemistry* **2021**, *21*, 2130-2137.
10. Pero, A. C.; Borghi, I.; Marin, D. O. M.; Policastro, V. B.; de Oliveira Junior, N. M.; Compagnoni, M. A.*European Journal of General Dentistry* **2016**, *5*, 122-126.
11. Yadav, P.; Mittal, R.; Sood, V. K.; Garg, R.*Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry* **2012**, *21*, 546-551.
12. Zafar, M. S. *Polymers* **2020**, *12*, 2299.
13. Díez-Pascual, A. M.*International Journal of Molecular Sciences* **2022**, *23*, 10288.
14. Jasim, B. S.; Ismail, I. J. *Journal of baghdad college of dentistry* **2014**, *26*, 18-23.
15. Hatamleh, M. M.; Maryan, C. J.; Silikas, N.; Watts, D. C. *Journal of Prosthodontics: Implant, Esthetic and Reconstructive Dentistry* **2010**, *19*, 258-262.
16. Agha, H.; Flinton, R.; Vaidyanathan, T. *Journal of Prosthodontics* **2016**, *25*, 647-655.
17. Waghmode, M. S.; Gunjal, A. B.; Mulla, J. A.; Patil, N. N.; Nawani, N. N. Biosynthesis, applications and remediation. *SN Applied Sciences* **2019**, *1*, 1-9.
18. Magalhães, A. P. R.; Ramos-Tonello, C. M.; Galli, M. Z.; Gomes, O. P.; Pacheco, L. E.; Fortulan, C. A.; Lisboa-Filho, P. N.; Furuse, A. Y.; Borges, A. F. S. *Journal of Prosthodontic Research* **2020**, *64*, 408-416.
19. Díez-Pascual, A. M. *Materials* **2022**, *15*, 3251.
20. Díez-Pascual, A. M. *Macromol* **2021**, *1*, 64-83.
21. Gad, M. M.; Fouda, S. M.; Al-Harbi, F. A.; Näpänkangas, R.; Raustia, A. *International journal of nanomedicine* **2017**, *12*, 3801.
22. Chaijareenont, P.; Takahashi, H.; Nishiyama, N.; Arksornnukit, M. *Dental materials journal* **2012**, *31*, 623-628.
23. Hasan, W. Y.; Ali, M. M.*Biomedical and Pharmacology Journal* **2018**, *11*, 1491-1500.
24. Kul, E.; Aladağ, L. İ.; Yesildal, R.*The Journal of prosthetic dentistry* **2016**, *116*, 803-810.
25. Hamedi-Rad, F.; Ghaffari, T.; Rezaii, F.; Ramazani, A. *Journal of Dentistry (Tehran, Iran)* **2014**, *11*, 495.
26. Ghafari, T.; HAMEDI, R. F.; Ezzati, B. **2014**.
27. Atla, J.; Manne, P.; Gopinadh, A.; Sampath, A.; Muvva, S. B.; Kishore, K.; Sandeep, C.; Chittamsetty, H. *Journal of clinical and diagnostic research: JCDR* **2013**, *7*, 1797.
28. Anusavice, K.; Shen, C.; Rawls, H. *Louis: Saunders* **2013**. *100*, 483-90.
29. Singh, Manoj & Kalaivani, R. & Subramanian, Manikandan & Sangeetha, N. & Kumaraguru, Arumugam. Applied Nanoscience. 2012, 3.10.1007/s13204-012-0115-7.
30. Kamyar, Shameli & Ahmad, Mansor & Zamanian, Ali & Sangpour, Parvanh & Shabanzadeh, Parvaneh & Abdollahi, Yadollah & Zargar, Mohsen. International journal of nanomedicine. 2012,7. 5603-10. 10.2147/IJN.S36786.
31. Article, Research & Princy, Geo & Gandhi, Nagendra & Renganathan, S.International Journal of Pharmacy and Pharmaceutical Sciences. 4,2012.