DOI: 10.7860/JCDR/2024/71223.19728

Original Article

Dentistry Section

Comparative Evaluation of Solubility of a Single Shade Resin Composite with Conventional Composite: An In-vitro Study

PRANAUTI SONAJE[1], FARHIN KATGE[2], SHILPA SHETTY[3], DEVENDRA PATIL[4], TRISHA PATEL[5]

BY-NC-ND

ABSTRACT

Introduction: Resin composites have been commonly used in restorative dentistry over the years. The longevity of restorations depends upon various physical properties like as solubility. Composite solubility can lead to deleterious effects on the polymer structure.

Aim: To evaluate and compare the solubility of a single shade resin composite in comparison to a conventional resin composite in artificial saliva.

Materials and Methods: In the present in-vitro study, 44 pellets (10 mm × 1 mm) were prepared from each material. The pellets were divided into two groups (n=22) based on the immersion period of two days and seven days. They were incubated, weighed using an analytical balance, and then immersed in artificial saliva. Weighing was done again after the completion of the immersion period, and solubility was calculated. Paired and independent sample t-tests were used to compare the solubility of both materials after two days and seven days.

Results: The differences of solubility values for the single shade composite and conventional composite at two and seven-day intervals were (p=0.031) and (p=0.019), respectively, which were statistically significant. On inter-group comparison, the difference in solubility of the single shade composite at two days was significantly lower compared to conventional composites (p=0.024). Whereas, no significant difference was observed in solubility values between both groups at seven days (p=0.102).

Conclusion: The performance of the single shade composite in terms of solubility was better in comparison with conventional composite.

Keywords: Aesthetics, Incubator, Resin composite, Solubility

INTRODUCTION

Rebuilding form, function, and aesthetics are important requisites when performing restorations in both adults as well as children. Among various restorative materials, resin composites have clinically shown some of the best results due to their aesthetics, translucency, good micromechanical bonding, biocompatibility, and mechanical properties. The essential qualities of resin composites are their optical properties and colour matching [1,2]. Commercially, composite resins are available in multiple enamel and dentin shades of different translucencies and opacities, which demands increased chairside time [1].

The "Blending Effect" (BE) or "chameleon effect" can be defined as the ability of a material to acquire a colour similar to that of its surrounding tooth structure. It also depends on the shades of enamel and dentin as they reflect different wavelengths of light [3,4]. As enamel has a highly mineralised prismatic structure, a small amount of water and low organic content, higher transmission of light occurs [5]. The quest for shortening restorative procedure time, increasing ease in shade matching, and reducing wastage of unused composite shades led to the evolution of universal shade composite which could match a wide range of classical shades.

Omnichroma is a newly developed single-shade resin composite. The structural colour phenomenon is based on the discrimination of wavelengths. Incident light interacts with nanostructures and supra-nano spherical filler particles in this resin composite and changes the transmission of light. This phenomenon allows shade matching of the composite material with the colour of the reference tooth [6].

In paediatric patients, along with the material handling properties, behaviour management skills, and time taken for the completion of the procedure plays a crucial role. Hence, materials that are easy to handle and aesthetically suitable with superior properties are preferred.

The main objective of carrying out restorative procedures in primary dentition is to maintain deciduous teeth in the arch until physiological exfoliation, for functional and aesthetic purposes. Hence, the longevity of the restoration placed on teeth is relevant. The longevity of the restorative material is affected by various physical properties, one of which is solubility. Solubility can be defined as the extent to which a material dissolves in a solvent at a given temperature [7].

Intraorally, resin composites are constantly exposed to an aqueous environment. The water that diffuses into the material causes dimensional changes as well as shear stress relaxation in the resin matrix [8]. This leads to polymer matrix expansion and an increases in the bulk of the resin composite. Solubility results in leakage of fillers, organic substances, and ions from the resin composite material. Some of these organic substances may induce delayed allergic reactions as they are potent irritants. Time and material composition have been shown to affect both material degradation and leakage [9].

In the literature, the solubility of composite resins in various solutions such as water, artificial saliva, and mouth rinses has been widely studied. However, studies on the solubility of single-shade composite are sparse [10-13]. Therefore, the present study aimed to measure and compare the solubility of a single-shade resin composite and conventional resin composite in artificial saliva at two-day and seven-days time intervals. The null hypothesis considered for the present study was that there was no significant difference between the solubility of single-shade composite and conventional composite. The alternative hypothesis stated that

there was a significant difference between the solubility of single-shade composite and conventional composite.

MATERIALS AND METHODS

This in-vitro study was carried out in the Department of Paediatric and Preventive Dentistry at Terna Dental College, Nerul, Navi Mumbai, Maharashtra, India, from September 2023 to November 2023. Ethical approval was obtained from the Institutional Ethical Review Board (TDC/EC/33/2022).

Inclusion criteria: The composite pellets with smooth margins and without distorted edges were included in the study.

Exclusion criteria: The partially or completely distorted composite pellets were excluded from the study.

Sample size calculation: The sample size was calculated in concordance with the results from a previous study reported by Cabadag OG and Gonulol N through G*Power software (version 3.1.9.7) [14]. The sample size calculated was 44 from the above method.

Procedure

Two composite materials were selected for solubility evaluation in this study. The type and composition of the materials are listed in [Table/Fig-1].

Material	Filler content	Filler rate	Manufacturer
Omnichroma	Fillers: Uniform sized supra-nano spherical silica-zirconia filler Matrix: UDMA, TEGDMA	Filler loading 79 wt% (68 vol %).	Tokuyama dental corporation (Taitouku, Tokyo, Japan)
Beautifil II	Bis-GMA, TEGDMA, S-PRG filler, multifunctional glass filler	83.3% (w) 0.01 µm-4 µm	Shofu, Kyoto, Japan
Artificial saliva	NaCl (400 mg/L), KCL (400 mg/L), $CaCl_2 \cdot 2H_2O$ (795 mg/L), $NaH_2PO_4 \cdot H_2O$ (690 mg/L) KSCN (300 mg/L), $Na_2S \cdot 9H_2O$ (5 mg/L), urea (1000 mg/L)		Wet Mouth, ICPA, India

[Table/Fig-1]: Materials used.

Preparation of specimens: To prepare the disc-shaped pellets, a Teflon mould with the dimensions (1±0.1 mm x 10±0.1 mm) was used. The mould was filled with composite material and pressed between two glass slides to extrude any excess material. The composite material was photopolymerised using an Light Emitting Diode (LED) curing unit on both sides for a total of 20 seconds according to the manufacturer's instructions. The pellets were removed from the moulds and examined for any minor irregularities. If present, they were removed by carefully grinding the sample with fine-grit sandpaper.

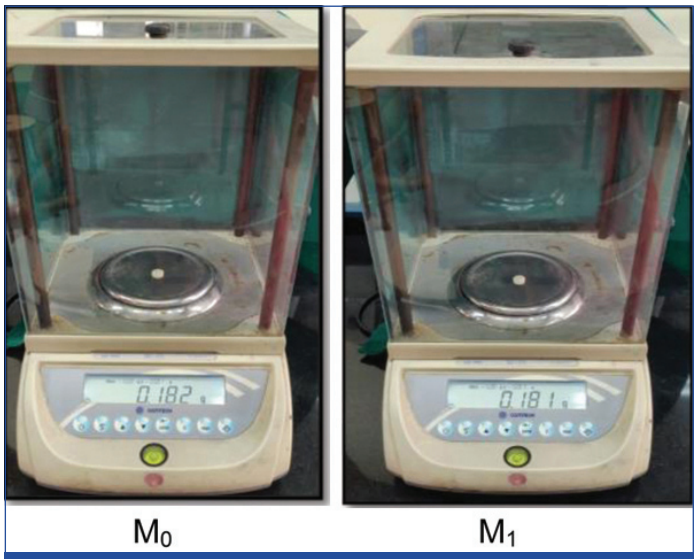
A total of 44 pellets were prepared for each restorative material, which was subdivided into two groups according to the storage time. The pellets were stored in artificial saliva for two days and seven days, respectively, before testing.

i. Group-1A (single-shade composite)-22 samples stored for two days in artificial saliva.
ii. Group-1B (single-shade composite)-22 samples stored for seven days in artificial saliva.
iii. Group-2A (conventional composite)-22 samples stored for two days in artificial saliva.
iv. Group-2B (conventional composite)-22 samples stored for seven days in artificial saliva.

Solubility measurement: Solubility measurements were conducted according to ISO 4049 standards [15].

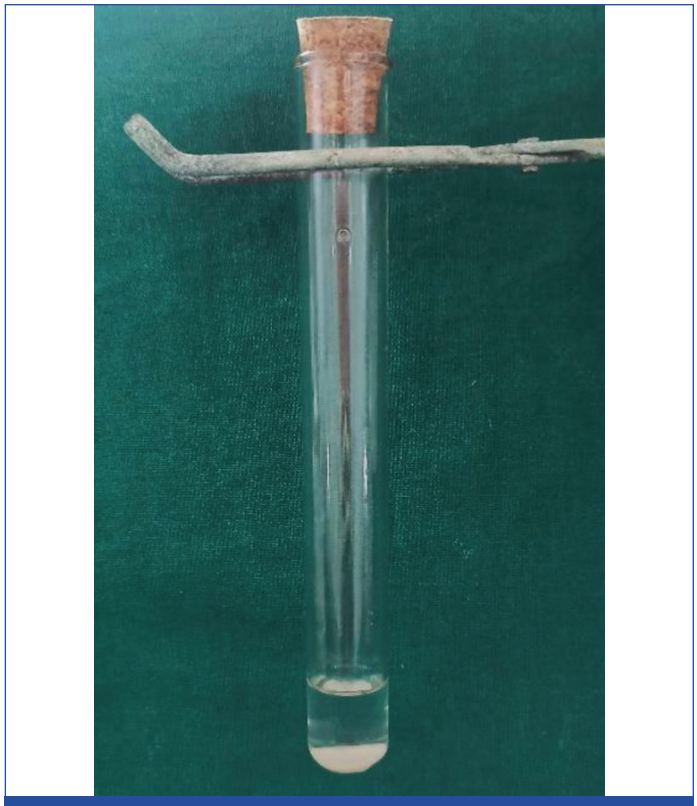
To measure the diameter and thickness of the composite pellets, a digital caliper was used. The diameter of each pellet was measured at two points 90 degrees to one another, and the mean diameter was calculated. Each pellet was measured for its thickness at the center and on its circumference at four equally spaced-out points, after which the mean thickness was calculated. The formula $V=\varpi \times r^2 \times h$ was used to calculate the volume (V) of each pellet, where r is the mean sample radius (diameter/2) and h is the mean sample thickness.

Each composite pellet was placed in separate labeled glass test tubes. To exclude light, the test tubes were wrapped in aluminum foil and placed in an incubator at 37°C for 24 hours [16]. Then the two pellets were removed and weighed using a digital balance (Contech CA 503) from Contech Instruments Ltd., Mumbai, India, with an accuracy of 0.001 g [Table/Fig-2]. This procedure was repeated three times until a constant mass, based on average calculation, was obtained, and the values were recorded in micrograms (µg) as m_0.



[Table/Fig-2]: Weighing of pellet for solubility measurement.

Pellets were then placed back in their respective test tubes containing 2 mL of artificial saliva [Table/Fig-3] for two days and seven days. After completing the respective storage periods, the pellets were removed with tweezers, washed with distilled water, dried using absorbent paper, and desiccated in a hot air oven at 37°C for 15 minutes. The weights were recorded again (m_1).



[Table/Fig-3]: Pellet placed in artificial saliva.

Solubility (S) was calculated as the change in weight before and after immersion in artificial saliva using the following formula [17]:

$$S=\frac{m_0-m_1}{V}$$

Where:

S=Solubility

m_0=Weight before immersion in artificial saliva

m_1=Weight after immersion in artificial saliva

V=Volume of composite pellet

STATISTICAL ANALYSIS

The data were entered into a Microsoft Excel spreadsheet which was then subjected to International Business Management (IBM) Statistical Package for Social Sciences (SPSS) for Windows version 22.0 software (Armonk, IBM Corp. NY) for statistical analyses. Means and standard deviations were calculated, and comparisons were performed using paired and independent t-tests. The level of significance was set as $p<0.05$.

RESULTS

The mean solubility values of the single shade composite after two and seven days were 4.36±2.9 µg/mm^3 and 6.73±4.9 µg/mm^3, respectively. Whereas, solubility values for the conventional composite after two and seven days were 5.25±5.1 µg/mm^3 and 9.64±8.0 µg/mm^3, respectively. On intra-group comparison, the differences in solubility values for the single shade composite at two and seven days intervals were statistically significant (p=0.031). Similarly, for the conventional composite, a significant difference was observed between the solubility values at two and seven days intervals (p=0.019) [Table/Fig-4].

Material	Storage period	Mean (µg/mm^3)	Standard deviation	p-value
Omnichroma (Single shade composite)	2 days	4.36	2.9	0.031
	7 days	6.73	4.9	
Beautifil II (Conventional composite)	2 days	5.25	5.1	0.019
	7 days	9.64	8.0	

[Table/Fig-4]: Solubility of composite materials.

In inter-group comparison, the difference in solubility of the single shade composite at two days was significantly lower compared to the conventional composites, with a p-value of 0.024. Whereas, at seven days, no statistical difference was observed in the solubility values between both groups (p=0.102).

DISCUSSION

The longevity of restorations is the most important requisite for measuring the success of restorative therapy. The retention of composite resin is affected by many variables, including patient, operator, material, and tooth-related factors. Some properties of composite restorations are affected by the oral environment, that has a negatively impacts the strength of the composite restoration. One such important property of a composite resin material is solubility. Hence, in the present study, the solubility of the newer single-shade composite resin was compared with that of the conventional composite resin. From the findings of the present study, the null hypothesis was rejected, and the alternative hypothesis was accepted, which showed a significant difference between the solubility of the single-shade composite and the conventional composite.

According to ISO 4049/2009, the solubility value of resin composite should be lower than 7.5 µg/mm^3 [15]. In the present study, the mean solubility values of the conventional composite were as follows: after two days-5.24 µg/mm^3, and after seven days-9.64 µg/mm^3, which was more than those of the single shade composite: after two days-4.36 µg/mm^3, and after seven days-6.73 µg/mm^3. Therefore, the results of the present study showed acceptable solubility after two days in artificial saliva for both materials, in accordance with ISO 4049/2009 standards [15]. The conventional composite showed higher solubility at 9.64 µg/mm^3, suggesting that it may be a contributing factor to increased microleakage.

Omnichroma, a single shade composite used in this study, used smart chromatic technology with the ability to capture structural colour. The smart monochromatic composite is composed of supra-nano spherical fillers, Silicon Dioxide (SiO_2), and zirconium dioxide (ZrO_2) with a particle size of 260 nm. These supra-nano fillers generate red-to-yellow colour, which combines with the colour of the surrounding tooth [18].

Solubility results in dissolution of a material in a solvent at a given temperature [7]. It also measures the amount of residual unconverted monomer released into the solution. This monomer may have the negatively impact the material structure [19]. Excessive solubility of a composite restoration can lead to matrix deformation and microleakage [20].

The solubility phenomenon is dependent on photopolymerisation and the composition of the resin composite [21]. Both studied composites contain the monomer Triethylene Glycol Dimethacrylate (TEGDMA), which has greater hydrophilicity and increased sorption capacity. The single shade composite resin matrix differs from the conventional composite matrix by the addition of Urethane Dimethacrylate (UDMA), which is less hydrophilic [22,23]. Composite solubility also depends on material since the solvent must penetrate the polymer for leachable components to be released. It is known that hydrophilic materials cause increased degradation through solubility compared to hydrophobic materials [23].

In a study done by Ozer S et al., the solubility of Filtek Z250 and Filtek Silorane composite resins were checked in mouth rinses and artificial saliva [16]. The results showed that the solubility values of both composite materials in artificial saliva were statistically insignificant. But, in the present study, the difference between the solubility values of single-shade composite resins was significantly lower compared to conventional composites at a two-day interval. The findings of the study by Gonulol N et al., stated that the solubility of Beautifil II composite was more than that of Filtek Z550 and Tetric N-Ceram, which are comparable to the findings of the present study [24]. However, the findings of the study by Bajabaa S et al., did not in accordance with the findings of the present study [20].

Bajabaa S et al., showed that Omnichroma presented highest microleakage when compared to Tetric-N-Ceram. In their study, microleakage was evaluated, which could be a confounding factor in solubility. This may be explained by the presence of TEGDMA resin matrix in Omnichroma, which has a lower molecular weight compared to Bis-GMA and UDMA in Tetric-N-Ceram, which considerably reduced polymerisation and microleakage [20]. The results of the study by Huang W et al., were comparable with the present study. In their research, they assessed the colour stability, water sorption, and solubility of eleven commercially available resin composite resins [17]. The authors observed that the solubility of Beautifil II composite resin was lesser than Beautifil Flow Plus F03, Charisma Diamond, Charisma, Denfil, DX.Universal, Filtek Z350 XT, and Tetric N-Ceram. They also noticed that the solubility values of Beautifil II were more when compared to Ceram.X One Universal, Filtek Z250, and Magnafill Putty [17].

The single-shade composite had better performance with a reduced solubility rate over the assessed time duration assessed. Hence, the newer material could be considered for restorations in paediatric dentistry.

Limitation(s)

This research with its limitation of being an in-vitro assay. Further clinical studies, including randomised and non-randomised trials with a larger sample size, are needed to support the results.

CONCLUSION(S)

In the present study, both composite materials showed solubility values within acceptable limits after two days. The single-shade composite showed lesser solubility than the conventional composite. The solubility of the composite resins was influenced by time, as both groups showed an increase in values after seven days.

REFERENCES

[1] Iyer RS, Babani VR, Yaman P, Dennison J. Color match using instrumental and visual methods for single, group, and multi-shade composite resins. J Esthet Restor Dent. 2021;33(2):394-400. Available from: https://doi.org/10.1111/jerd.12621.

[2] van de Sande FH, Moraes RR, Elias RV, Montagner AF, Rodolpho PA, Demarco FF. Is composite repair suitable for anterior restorations? A long-term clinical study. Clin Oral Investig. 2019;23(6):2795-803. Available from: https://doi.org/10.1007/s00784-018-2722-5.

[3] Paravina RD, Westland S, Imai FH, Kimura M, Powers JM. Evaluation of blending effect of composites related to restoration size. Dent Mater. 2006;22(4):299-307. Available from: https://doi.org/10.1016/j.dental.2005.04.022.

[4] Paravina RD, Westland S, Kimura M, Powers JM, Imai FH. Color interaction of dental materials: Blending effect of layered composites. Dent Mater. 2006;22(10):903-08. Available from: https://doi.org/10.1016/j.dental.2005.11.018.

[5] Arikawa H, Kanie T, Fujii K, Takahashi H, Ban S. Effect of filler properties in composite resins on light transmittance characteristics and color. Dent Mater J. 2007;26(1):38-44. Available from: https://doi.org/10.4012/dmj.26.38.

[6] Kobayashi S, Nakajima M, Furusawa K, Tichy A, Hosaka K, Tagami J. Color adjustment potential of single-shade resin composite to various-shade human teeth: Effect of structural color phenomenon. Dent Mater J. 2021;40(4):1033-40. Available from: https://doi.org/10.4012/dmj.2020-364.

[7] Anusavice KJ, Shen C, Rawls HR. Phillips' science of dental materials. 18th Edition, Elsevier/Saunders, St. Louis. 2013. Available from: https://www.scirp.org/reference/referencespapers?referenceid=3087571.

[8] Feilzer AJ, de Gee AJ, Davidson CL. Relaxation of polymerization contraction shear stress by hygroscopic expansion. J Dent Res. 1990;69(1):36-39. Available from: https://doi.org/10.1177/00220345900690010501.

[9] Ferracane JL. Hygroscopic and hydrolytic effects in dental polymer networks. Dent Mater. 2006;22(3):211-22. Available from: https://doi.org/10.1016/j.dental.2005.05.005.

[10] Zhang Y, Xu J. Effect of immersion in various media on the sorption, solubility, elution of unreacted monomers, and flexural properties of two model dental composite compositions. J Mater Sci Mater Med. 2008;19(6):2477-83. Doi: 10.1007/s10856-008-3369-6.

[11] Asaoka K, Hirano S. Diffusion coefficient of water through dental composite resin. Biomaterials. 2003;24(6):975-79.

[12] Musanje L, Darvell BW. Aspects of water sorption from the air, water and artificial saliva in resin composite restorative materials. Dent Mater. 2003;19(5):414-22.

[13] Koizumi H, Satsukawa H, Tanoue N, Ogino T, Nishiyama M, Matsumura H. Effect of metal halide light source on hardness, water sorption and solubility of indirect composite material. J Oral Sci. 2005;47(4):165-69.

[14] Cabadag OG, Gonulol N. The effects of food-simulating liquids on surface roughness, surface hardness, and solubility of bulk-fill composites. J Adv Oral Res 2021;12(2):245-53. Available from: https://doi.org/10.1177/2320206820988451.

[15] EN ISO, 4049, Dentistry-polymer-based filling, restorative and luting materials, international organization for standardization, Geneva, Switzerland, 1988.

[16] Ozer S, Sen Tunc E, Tuloglu N, Bayrak S. Solubility of two resin composites in different mouthrinses. Biomed Res Int. 2014;2014:580675. Available from: https://doi.org/10.1155/2014/580675.

[17] Huang W, Ren L, Cheng Y, Xu M, Luo W, Zhan D, et al. Evaluation of the color stability, water sorption, and solubility of current resin composites. Materials (Basel). 2022;15(19):6710.

[18] Chu SJ, Trushkowsky RD, Paravina RD. Dental color matching instruments and systems. Review of clinical and research aspects. J Dent. 2010;38(Suppl 2):e02-e16. Available from: https://doi.org/10.1016/j.jdent.2010.07.001.

[19] Goncalves L, Amaral CM, Poskus LT, Guimaraes JG, Silva EM. Degradation of resin composites in a simulated deep cavity. Braz Dent J. 2014;25(6):532-37. Available from: https://doi.org/10.1590/0103-6440201300089.

[20] Bajabaa S, Balbaid S, Taleb M, Islam L, Elharazeen S, Alagha E. Microleakage evaluation in class v cavities restored with five different resin composites: In-vitro dye leakage study. Clin Cosmet Investig Dent. 2021;13:405-11. Doi: 10.2147/CCIDE.S331426.

[21] Espíndola-Castro LF, Durao MA, Pereira TV, Cordeiro AB, Monteiro GM. Evaluation of microhardness, sorption, solubility, and color stability of bulk fill resins: A comparative study. J Clin Exp Dent. 2020;12(11):e1033-e1038.

[22] Porto IC, Almeida AGA. Evaluation of short-and medium-term sorption and solubility of methacrylate or silorane-based composite resins in artificial saliva. Rev Odontol UNESP. 2013;42(3):176-81. Available from: https://doi.org/10.1590/S1807-25772013000300006.

[23] Leal JP, da Silva JD, Leal RFM, Oliveira-Júnior CDC, Prado VLG, Vale GC. Effect of mouthwashes on solubility and sorption of restorative composites. Int J Dent. 2017;2017:5865691. Doi: 10.1155/2017/5865691.

[24] Gonulol N, Ozer S, Sen Tunc E. Water sorption, solubility, and color stability of giomer restoratives. J Esthet Restor Dent. 2015;27(5):300-06. Available from: https://doi.org/10.1111/jerd.12119.

PARTICULARS OF CONTRIBUTORS:

1. Postgraduate Student, Department of Paediatric and Preventive Dentistry, T.P.C.T.s Terna Dental College, Navi Mumbai, Maharashtra, India.
2. Professor and Head, Department of Paediatric and Preventive Dentistry, T.P.C.T.s Terna Dental College, Navi Mumbai, Maharashtra, India.
3. Reader, Department of Paediatric and Preventive Dentistry, T.P.C.T.s Terna Dental College, Navi Mumbai, Maharashtra, India.
4. Reader, Department of Paediatric and Preventive Dentistry, T.P.C.T.s Terna Dental College, Navi Mumbai, Maharashtra, India.
5. Postgraduate Student, Department of Paediatric and Preventive Dentistry, T.P.C.T.s Terna Dental College, Navi Mumbai, Maharashtra, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:

Dr. Farhin Katge,
T.P.C.T.s Terna Dental College, Nerul West, Sector 22,
Navi Mumbai-400706, Maharashtra, India.
E-mail: pedotdc@gmail.com

PLAGIARISM CHECKING METHODS: [Jain H et al.]

- Plagiarism X-checker: Apr 10, 2024
- Manual Googling: May 14, 2024
- iThenticate Software: Jun 05, 2024 (16%)

ETYMOLOGY: Author Origin

EMENDATIONS: 6

AUTHOR DECLARATION:

- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Apr 10, 2024**
Date of Peer Review: **May 09, 2024**
Date of Acceptance: **Jun 06, 2024**
Date of Publishing: **Aug 01, 2024**