EVALUATION OF COLOR STABILITY OF POLYMETHYLMETHACRYLATE (PMMA) VERSUS POLYETHERETHERKETONE PEEK, INVITRO STUDY.

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ABSTRACT:

Aim of the work: The aim of this study to evaluate color stability of PMM and PEEK as denture base materials. Materials and methods: Twenty specimens of PMMA and PEEK were prepared according to ISO/FDIS 20795-1 by milling machine with (50 ± 1) mm diameter and (0,5 ± 0,1) mm thickness. All PMMA and PEEK specimens were stored in the oven for 24 h ± 30 min at (37 ± 1) °C. Then ten specimens of each PMMA and PEEK were stored in the dark in a laboratory environment. Another 10 specimens of PEEK and PMMA were aging according to ISO 7491:2000 guidelines. The specimen's colors were measured before and after aging using a portable Reflective spectrophotometer. The color changes (ΔE) of the specimens were measured according to ISO/FDIS 20795-1, statistical analysis was made by SPSS Statistical Package of Social Science version 25. Results: Before aging, highest color stability mean value was exhibited in PEEK (ΔE = 1.8 ± 0.12). lowest color stability mean value was exhibited in PMMA (ΔE = 4.6 ± 0.35). After artificial aging, PEEK showed the least color alteration with a ΔE value of (3.6 ± 0.21), then PMMA (ΔE = 7.9 ± 0.77). Conclusion: Within the limitations of this study, PEEK is the best color stable, while PMMA exhibited higher susceptibility to color change.

KEYWORDS: Color Stability, PEEK, Denture Base Materials, Artificial Aging, Spectrophotometer

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INTRODUCTION

The use of resins as denture base materials was initiated by Dr. Leo Bakeland in 1909 by using phenol formaldehyde resin. Because of its outstanding esthetics, easy processing, relining, and repair techniques [1-3]. Dr Walter Wright in 1937 introduced Polymethylmethacrylate (PMMA) in dentistry. Nowadays, PMMA became the most widely used materials in dentistry due to their biocompatibility, stability in the oral environment, easy manipulation, processability, good aesthetics, accurate fit, and simpler processing reparability[4-6]. All acrylic dentures are subjected to intraoral or extra oral stresses and environmental changes. However, this material is not ideal in every respect [7]. So as to overcome the limitations of PMMA, Polyetheretherketone PEEK has been introduced. It is a polymeric material that consists of an aromatic compound molecular chain that is interconnected by ketone and ether functional groups[8]. Initially, PEEK was originally developed for the automobile and aerospace industries; then in 1990, PEEK was introduced for medical uses as spinal and hip implants owing to its outstanding biological, chemical, thermal, and mechanical properties. In 1999, PEEK was introduced dental market as a high performance, chemically inert biomaterial known for its bioinert characteristics [9]. The clinical longevity of any denture base material is evaluated by its water absorption ability, polymerization shrinkage, dimensional stability, color stability and polishing ability [10-12]. Color stability of dental materials reflects its clinical success and considered as essential key factor for its performance inside patients' mouth. For denture base materials, any color changes reflect damaged material and/or aging, consequently, denture base color should match the color and appearance of the underlying tissues [13, 14].Three types of discolorations are generally described: (i) external discoloration due to the accumulation of plaque and surface stains (extrinsic stain), (ii) surface or subsurface color alteration and (iii) intrinsic discoloration. Extrinsic discoloration is mainly caused by colorants contained in beverages and foods. It has been proven that common drinks and food ingredients could cause significant change in surface color. Surface or subsurface color alteration implying superficial degradation or slight penetration and reaction of staining agents within the superficial layer of denture base materials (absorption) and body. Intrinsic discolorations are due to physicochemical reactions in the deeper portion of the restoration e.g., incomplete polymerization with residual monomer left unreacted, high degree of water absorption, deterioration of intrinsic pigments and dissolution of material components can influence color stability and considered as most common intrinsic factors cause color changes, besides, presence of porosity caused by the excessive heating or the change in pressure values during material processing [15-19]. The aim of this study to evaluate color stability of PMM and PEEK as denture base materials. The null hypotheses were: (1) there will be no significant difference in color stability between PMMA and PEEK. (2) there will be no significant difference in color stability of each PMMA and PEEK group before and after ageing.

Materials and Methods:

Specimens' preparation: Twenty specimens of PMMA (Lucitone 199, Dentsply International Inc. Chicago, USA) and PEEK (Bredent, Weissenhorner, Senden – Germany) were prepared according to ISO/FDIS 20795-1 [20] by milling machine (liner precision saw, Isomet 500, buehler, USA) with (50 ± 1) mm diameter and (0,5 ± 0,1) mm thickness and that the top and bottom surfaces were flat. Specimens' aging: All PMMA and PEEK specimens were Stored in the oven for 24 h ± 30 min at (37 ± 1) °C. Then ten specimens of each PMMA and PEEK were stored in the dark in a laboratory environment.Another 10 specimens of PEEK and PMMA were aging according to ISO 7491:2000 [21] guidelines. Half of each specimen of PEEK and PMMA was covered with aluminum foil and the whole specimen was stored in water at 37 °C then exposure to intense ultraviolet (UV) light with alternating cycles of moisture and temperature. After exposure, the aluminum foil was removed before color comparison between nonaged/covered/uncovered half of specimen and nonaging specimens was measured. Color measured: The specimen's colors were measured before and after aging using a portable Reflective spectrophotometer (X-Rite, model RM200QC, Neu-Isenburg, Germany). A white background was selected and measurements were made according to the CIE L*a*b* color space (figure 1). The color changes (ΔE) of the specimens were evaluated using the following formula: $\Delta ECIELAB = (\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2})^{1/2}$. Where: L* = lightness (0-100), a* = change the color of the axis red/green and b* = color variation axis yellow/blue.

Figure 1: Color testing by spectrophotometer.

Statistical analysis: The data were collected and tabulated and statistically analyzed by an IBM compatible personal computer with SPSS Statistical Package of Social Science version 25 (IBM SPSS statistics for windows, version 25, Armnok, NY: IBM Corp).

Two types of statistical analysis were done:

- Descriptive statistics was expressed in mean ($\bar{x}$) and standard deviation (SD).
- Analytic statistics: Student t-test was used to determine statistical significance before and after aging of each material (evaluate effect of aging),

and to determine statistical difference between two materials before and after aging (compare color stability of two material).
- p-value of < 0.05 was considered statistically significant.

Results:

The color stability of the PMMA and PEEK was evaluated based on the ΔE values calculated from the color measurements before and after artificial aging. ΔE means ± standard deviations are listed in Table 1. ΔE values represent the overall color change, higher ΔE values indicating greater color change. Before aging, the lowest ΔE value and highest color stability mean value was exhibited in PEEK (1.8 ± 0.12). Highest ΔE value and lowest color stability mean value was exhibited in PMMA (4.6 ± 0.35). After artificial aging, PMMA and PEEK experienced an increase in ΔE values, indicating color change due to aging. PEEK showed the least color alteration with a ΔE value of (3.6 ± 0.21), PMMA (ΔE = 7.9 ± 0.77). t- test analysis showed statistically significant differences in color stability before aging between PEEK and PMMA (The t-value is -45.97008. The p-value is < 0.00001) and after aging (t-value is -159.2714. The p-value is < 0.00001). Also, t- test showed statistically significant differences of PEEK before and after aging (t-value is -58.07636. The p-value is < 0.00001) and PMMA before and after aging (t-value is -33.17007. The p-value is < 0.00001) The results demonstrate that PEEK exhibited superior color stability compared to PMMA.

Table 1: Color stability means ± SDs of PMMA and PEEK groups.

Materials	Before Aging (ΔE)	After Aging (ΔE)	ΔE Change
PEEK	1.8 ± 0.12^{aA}	3.6 ± 0.21^{bA}	1.8
PMMA	4.6 ± 0.35^{aB}	7.9 ± 0.77^{bB}	3.3

Means with the different small superscripted letters in the same row and the different capital superscripted letters in the same column demonstrated statistically significant differences (p ≤ 0.05).

Discussion:

Color is considered as an important criterion of any denture material, consequently, its stability during material's entire survivability time considered as a major factor of prosthesis success or failure [22]. Dental prostheses discoloration varies accord¬ing to type of resin matrix, percentage and filler size incorporated fillers distribution, composition and polymerization mode age, restoration processing mode, also extrinsic factors affect the color stability of dental prosthesis such as, change in humidity and ph. All these neces¬sitate the application of effective cleaning methods [23-26]. In current study, Statistical analysis confirmed statistically significant differences in color stability before aging between PEEK and PMMA (p-value is < 0.00001) and after aging (p-value is < 0.00001); therefore, the first null hypothesis was rejected. Also, Statistical analysis showed statistically significant differences of PEEK before and after aging (p-value is < 0.00001) and PMMA before and after aging (p-value is < 0.00001); therefore, the second null hypothesis was rejected. In current study, PEEK groups showed least color alternation and high color stability compared to PMMA, this is due to: (i) Polyether ether ketone (PEEK) is generally considered hydrophobic. This means that PEEK repels water and other polar liquids. The water contact angle of PEEK is typically greater than 80 degrees, indicating its hydrophobic nature [27-29], while (ii) PMMA contain some hydrophilic polymer e.g., Ethylene glycol dimethacrylate (EGDMA) which is generally considered hydrophilic due to the presence of polar carbonyl groups that can form hydrogen bonds. Its inherent nature is more towards attracting water molecules than repelling them, so that it can absorb water and increase incidence of color change [30-33]. (iii) PEEK is strengthened with 20% ceramic fillers. These ceramic fillers, with a grain size between 0.3 and 0.5 µm which resistance to water sorption and color change [34,35], while (iv) PMMA have Benzoyl peroxide as initiator which can negatively impact color stability by unreacted benzoyl peroxide can undergo further oxidation or degradation, leading to yellowish discoloration and potentially even darkening [36,37]. Douglas et al. [38] claimed that (ΔE) values greater than 5.6 are visually noticed and clinically unacceptable, so that, ΔE of PEEK (1.8 ± 0.12 and 3.6 ± 0.21) indicate it clinically acceptable, while, PMMA showed clinically unacceptable ΔE values (4.6 ± 0.35 and 7.9 ± 0.77).Results of current study are consistent with many studies, Heimer [39] claimed that PEEK material showed the significantly lowest color changes after one week immersion in the following media; red wine, curry, and chlorhexidine as compared to PMMA and composite, he confirmed that PEEK material have a reduced degree of discoloration.

Conclusion:

Within the limitations of this study, Current study provides valuable insights into the color stability of PEEK and PMMA denture base materials. PEEK is the best color stable, while PMMA exhibited higher susceptibility to color change. Clinicians should carefully weigh the advantages and limitations of each material to ensure optimal esthetic outcomes.

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