Assessment of the Surface Roughness and Colour Stability of Polyetheretherketone and With an Efficient Chairside Polishing Method for Dental Prosthetics

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**Abstract**: Polyetheretherketone (PEEK),(-C6H4-O-C6H4-O-C6H4-CO-)n, is a semi-crystalline, thermoplastic engineering compound, characterized by its ultra durable mechanical properties and inert chemical nature. It is a part of the poly(aryl ether ketone) polymer family, (PAEK) . PEEK is obtained when ketone and ether functional groups are made to bind with acyl rings. PEEK has ultrahigh mechanical performance and is a chemically inert material much like its parent compound polyaryletherketone (PAEK). Its reputation extends to the biomedical field, particularly in dental , spine and orthopedic applications, where it is a highly sought-after biomaterial. In dentistry, PEEK is utilized for various components, such as removable denture frames, crowns, fixed partial dentures, and implant bodies. It is also sought after due to other properties such as biocompatibility , aesthetic mechanical and non reactive nature. Anticipated future demand for dental prostheses made from these materials is driven by escalating precious metal prices and concerns about metal allergies in dental applications.This study aims to evaluate the effects of shofu super snap kit on the surface roughness and the impact of various beverages on the color stability of PEEK. Almost any material used in dentistry must have a surface which can be highly polished, this is to avoid accumulation of plaque, thereby reducing microbial accumulation. Polishing of any material can be achieved both chair side or in lab. Since one of the indication of PEEK is to be used as crowns hence chair side polishing methods need to be evaluated. To achieve polishing in other materials such as cermaics , glazing is done. While composites are polished using chair side methods. One such method is using shofu super snap kit which is widely used in every day clinical practice. The goal of this study is to identify an effective chairside polishing approach for PEEK dental prosthetics.To check colour stability ,fifteen randomly chosen PEEK specimens were immersed in one of the following solutions: distilled water, coffee and aereted drinks for thirty days at 37c. A colorimeter was then employed to measure color. Color assessment was carried out using the CIE L\*a\*b\* system, a three-dimensional color space comprising brightness (L), red-green (a), and yellow-blue (b) components. The Wilcoxon sign rank test revealed that in all the variables ra, rq, and rz, the surface roughness reduced significantly after polishing with Shofu super snap kit.The ΔE values of color stability was significantly different between the groups as assessed by one way ANOVA. Further post hoc test was done to assess the differences between the groups. It was revealed that coffee had the maximum colour change followed by coca cola and the least colour change was shown by distilled water.the use of the Shofu Super Snap series resulted in a clinically acceptable surface roughness for PEEK, demonstrating effective polishing and making it a viable chairside option. Also in the aspect of colour stability, distilled water resulted in the minimum and coffee resulted in maximum colour stability.

**Keywords**- PEEK, Innovation, colour stability, surface roughness, polishing

# Introduction

Polyetheretherketone (PEEK) is a commonly employed engineering plastic in industrial settings, prized for its consistent physical characteristics and exceptional durability. Its reputation extends to the biomedical field, where it has become a sought-after biomaterial for orthopedic and spine cages. [(Ojha et al., 2023; Su et al., 2023)](https://paperpile.com/c/57HK5Q/Pd6rn+Nbk39). With the chemical formula (-C6H4-O-C6H4-O-C6H4-CO-)n, it is a semi-crystalline thermoplastic biomaterial that is a member of the poly(aryl ether ketone) polymer family, which is based on ultra-high molecular weight polyethylene . In dentistry, PEEK is utilized for various purposes such as creating implant bodies, implant structures, crowns, fixed partial dentures, and frameworks for removable dentures [(Bathala et al., 2019)](https://paperpile.com/c/57HK5Q/GQfkq). The demand for dental prosthetics made from these materials is expected to rise in the future, driven by increasing prices of precious metals and concerns about metal allergies in dental applications [(Panayotov et al., 2016)](https://paperpile.com/c/57HK5Q/djL9M).A veneering composite resin material is also required for aesthetics because the material has an opaque grayish-brown or pearl-white tint[(Choi et al., 2005)](https://paperpile.com/c/57HK5Q/Xd4VL). The clinical lifetime of dental restorations can be assessed by considering pertinent factors such as dimension stability, color stability, polishing ability, water absorption, and polymerization shrinkage.[(Ajay et al., 2023; Chokkattu et al., 2023; Padarthi et al., 2023)](https://paperpile.com/c/57HK5Q/zlNhc+3KKcS+sUkxk) For dental prosthetics, a smooth surface is crucial to enhance comfort for the tongue and prevent excessive adhesion of dental plaque[(Mizutani et al., 2021)](https://paperpile.com/c/57HK5Q/6yYUm). While the prosthetic device may be sufficiently polished in the laboratory, additional polishing is frequently required during chairside adjustments [(Sarac et al., 2006)](https://paperpile.com/c/57HK5Q/fnTAR). Ideally, the ultimate polished prosthesis should possess a surface roughness measuring below 0.2 μm, a critical threshold aimed at preventing excessive adhesion of dental plaque. [(Dharman et al., 2023; S. Sindhu et al., 2023; Sreenivasagan et al., 2023)](https://paperpile.com/c/57HK5Q/vepKX+8PUZK+iWq7a) Moreover, a coarse occlusal surface contributes to a diminished contact area, thereby elevating the likelihood of abrasive wear [(Ishida et al., 2023)](https://paperpile.com/c/57HK5Q/mnUHN). It but also plays a crucial role in the accumulation of bacterial plaque. There is a direct connection between the surface texture and the formation of biofilm. Therefore, it is essential to polish dental prostheses to minimize surface roughness [(Bürgers et al., 2010)](https://paperpile.com/c/57HK5Q/HNsWB). This can be achieved using various polishing tools [(Sturz et al., 2015)](https://paperpile.com/c/57HK5Q/USm55). Various polishing kits have been developed for this specific purpose, including tungsten carbide finishing burs, silicone rubber discs, diamond rotary instruments, and abrasive discs coated with silicon carbide or aluminum oxide [(Pietrokovski et al., 2022)](https://paperpile.com/c/57HK5Q/co5Uo). If PEEK has to be used as an implant material in the anteriors, color stability is also crucial. The oral environment influences veneering material performance in two main ways: first, by extrinsic coloring from food consumed, such as coffee, acidic goods, or mouth rinses, where chemical adhesion causes a discoloration effect [(Alsilani et al., 2022)](https://paperpile.com/c/57HK5Q/64Uvp). The second route involves intrinsic components associated with aging, heredity, and interpreting the emotional state of implanted restorations. Another important characteristic that requires in-depth research is the discolouration. A spectrophotometer is used to measure the restorative material's color stability over an extended length of time [(Abhay et al., 2021)](https://paperpile.com/c/57HK5Q/EuZQ5). There is limited information available on the polishing of PEEK, as only few studies have explored both laboratory and chairside procedures. Additionally, the existing literature lacks comparisons with polishing techniques used for other dental materials, given the various types of PEEK [(Heimer et al., 2017)](https://paperpile.com/c/57HK5Q/hUYqD). This study aims to evaluate the effects of shofu super snap kit on the surface roughness and the impact of various beverages on the color stability of PEEK. The goal is to identify an effective chairside polishing approach for dental prosthetics.

# Materials and Methods

This invitro study was conducted in the white lab associated with the department of prosthodontics in a private dental college, chennai. The sample size was calculated to be 15 with 95 power from a study done by Kosuke Kurahashi et al in 2020 [(Kurahashi et al., 2020)](https://paperpile.com/c/57HK5Q/bJ6Cz). PEEK samples were fabricated in the form of discs with dimensions of 10mm in diameter and 10mm in height. These specimens were created using computer-aided design and subsequently machined using the RXP500 DSC milling machine from Röders GmbH in Soltau, Germany (3 shape) . Subsequent to this, all specimens underwent manual trimming, and the disc bases were polished in a water environment using the Shofu super snap kit. The distinct colors of the burs signify varying coarseness levels. Following this, the samples underwent ultrasonic cleaning with 70% isopropanol for 10 minutes. Finally, the PEEK blocks were rinsed thrice with distilled water. Measurements of root mean square average (Rq), Rz (the difference between the highest "peak" and the lowest "valley" on the surface), and surface profile mean deviation (Ra) were conducted using a laser microscope and a contact profilometer.Each base surface was measured at three different positions, and the representative value for each specimen was determined by averaging the squared values. The commonly used surface roughness parameter, Ra, denotes the average surface roughness in two dimensions, and an extension of Ra yields the three-dimensional surface roughness.Thirty days at 37oC, fifteen randomly chosen PEEK specimens were immersed in one of the following solutions: distilled water, coffee (Nescafé®Classic; NESTLÉ), or Coca-Cola (COCA-COLA®; The Coca-Cola company). The pH of the solutions was determined with WINLAB, Batch: 14037-1, a pH indicator. Every twelve hours, immersing solutions were changed. Measurements of color were taken both before and after immersion. A colorimeter (Dr. Lange Microcolor Data Station; Braive Instruments) with an 8o measuring geometry and D65 light, as per DIN 5053 standards, was employed to measure color. Color assessment was carried out using the CIE L\*a\*b\* system, a three-dimensional color space comprising brightness (L), red-green (a), and yellow-blue (b) components. To determine L\*, a\*, and b\* for each specimen before and after immersion, the average of six successive measurements taken at the center of the specimens was calculated. The equation ΔE = [(ΔL\*)² + (Δa\*)² + (Δb\*)²]^(1/2) was utilized to compute the overall color change (ΔE) for each specimen, where ΔL\*, Δa\*, and Δb\* represent the variations in L\*, a\*, and b\* before and after staining.

# Statistical analysis

The software IBM SPSS, Version 23.0 (IBM Corp., Armonk, NY, USA), was used to analyze the data. To assess the normality of the data, Shapiro Wilk test was done (Saadh et al., 2024) (Almatrafi et al., 2024). Wilcoxon sign rank test was used to compare the sample means of surface roughness before and after polishing. One way ANOVA with tukey’s post hoc test was done to assess the differences between the colour change in PEEK sample immersed in various solutions. A 0.05 level of significance was applied (p>0.05).

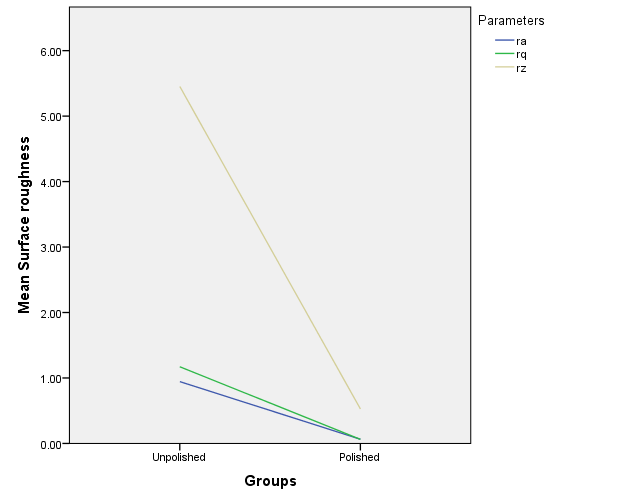
# Results

There are 30 samples present in the study which were assessed for surface roughness and colour change. 15 samples each were assessed for both the parameters. The Wilcoxon sign rank test revealed that in all the variables ra, rq, and rz, the surface roughness reduced significantly after polishing with Shofu super snap kit (Table 1 and Figure 1).

On backdrops of both white and black, the values L\*, a\*, and b\* were recorded, and the computed. The ΔE values of color stability was significantly different between the groups as assessed by one way ANOVA (Table 2). Further post hoc test was done to assess the differences between the groups. It was revealed that coffee had the maximum colour change followed by coca cola and the least colour change was shown by distilled water (Table 3 and Figure 2).

**Table 1 :** Wilcoxon sign rank test showing the mean differences in the assessment of surface roughness

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Variables** | **Mean** | **Standard deviation** | **Z value** | **p value** |
| Ra unpolished | 0.944 | 0.734 | 2.023 | 0.043\* |
| Ra polished | 0.0640 | 0.027 |
| Rq unpolished | 1.171 | 0.914 | 2.083 | 0.039\* |
| Rq polished | 0.062 | 0.019 |
| Rz unpolished | 5.453 | 4.305 | 3.156 | 0.029\* |
| Rz polished | 0.526 | 0.185 |



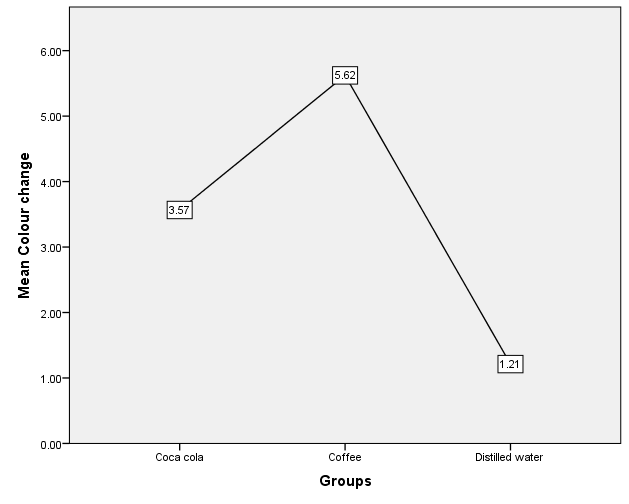
**Figure 1:** Surface roughness of PEEK before and after polishing

**Table 2 :** One way ANOVA showing the mean differences in the assessment of colour change

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Solutions | Mean土SD | Sum of Squares | Mean squares | F value | P value |
| Coca Cola | 3.56土0.44 | 48.694 | 24.34 | 128.77 | 0.000 |
| Coffee | 5.62土0.50 |
| Distilled water | 1.21土0.33 |

**Table 3:** Post hoc test showing the mean differences in the colour change between groups

|  |  |  |  |
| --- | --- | --- | --- |
| (I) Groups | (J) Groups | Mean Difference (I-J) | P value |
| Coca Cola | Coffee | -2.056 | 0.000 |
|  | Distilled water | 2.354 | 0.000 |
| Coffee | Coca Cola | 2.056 | 0.000 |
|  | Distilled water | 4.41 | 0.000 |
| Distilled water | Coca Cola | -2.354 | 0.000 |
|  | Coffee | -4.41 | 0.000 |



**Figure 2:** Colour change of PEEK before and after immersing in different liquids

# Discussion

Raimondo et al compared the surface finish of unglazed porcelain produced by six different polishing techniques, with that produced by glazing.18 The Shofu kit was the only kit, among those tested, that did not come with polishing paste. [(Ramakrishnan et al., 2023; Shenoy & Maiti, 2023; J. S. Sindhu et al., 2023)](https://paperpile.com/c/57HK5Q/NkMdd+iITP3+kzYR8) It produced a surface that was least acceptable visually, however, its results rated better when examined under the scanning electron microscope. The researchers recommended this kit for smoothing porcelain, if used in conjunction with a porcelain polishing paste containing fine diamond particlesShofu is accepted in both co posite and ceramics Similar resulats were found by other authors [(Kasabwala et al., 2021; Rajeshkumar & Lakshmi, 2021; Varghese et al., 2023)](https://paperpile.com/c/57HK5Q/ClQhg+zIeaR+8hksu)Coarser abrasives give rise to rougher porcelain surfaces. Klausner et al 20 showed that diamond produces the roughest surface and that porcelain finishing stone also produces considerable roughness. These researchers found the Shofu finishing kit was capable of producing as smooth a surface as glazed porcelainSurface roughness is usually expressed by tiny differences in surface height of a particular material or workpiece. [(Keerthana & Ramesh, 2021; Murugesan, 2021; Tiwari & Jain, 2021)](https://paperpile.com/c/57HK5Q/PVxF6+rBeTZ+EpmNL)[(Keerthana & Ramesh, 2021; Murugesan, 2021; Subramanian et al., 2021; Tiwari & Jain, 2021)](https://paperpile.com/c/57HK5Q/PVxF6+rBeTZ+EpmNL+1qzwj) The biggest difference between the peak and valley (Rz) or the individual variations of the peaks and valleys average (Ra value). The square root of the total squares of the different heights and depths from the mean line is known as root mean square roughness, or Rq [(Dobes et al., 2017)](https://paperpile.com/c/57HK5Q/YlULq).Despite the introduction of various new biomaterials for biomedical applications, PEEK has found widespread use in dental applications. The crucial properties of restorative materials, including abrasion resistance, color stability, and displacement resistance, underscore the significance of PEEK in this context [(Khurshid et al., 2022)](https://paperpile.com/c/57HK5Q/UelCm). Dental technicians and dentists are grappling with the challenge of selecting an appropriate polishing method, given the multitude of methods available and the absence of precise guidelines [(Akay & Ersöz, 2020)](https://paperpile.com/c/57HK5Q/zlmpc).The quality of the surface is contingent on several factors such as the type of polishing instrument, speed, applied pressure, surrounding environment, and the desired level of abrasive wear on the dental restorative material. The available polishing techniques include 2-body abrasion, which involves the use of grinding tools as well as bonded and coated abrasives, and 3-body abrasion, which entails the application of polishing pastes containing substances like aluminum oxide or diamond particles [(Jones et al., 2004)](https://paperpile.com/c/57HK5Q/ZtTNU). Analysis of surface roughness using a profilometer and Vickers hardness measurements are tests employed to assess the surface properties of a material. But even while the material's surface structure is quantified by these mechanical tests, the material's surface topography is not fully revealed by them [(Gungor et al., 2014)](https://paperpile.com/c/57HK5Q/fYHK4). The material's topography is examined and surface changes are meticulously observed using methods including confocal laser scanning microscopy (CLSM), atomic force microscopy (AFM), three-dimensional (3D) optical profilometers, and scanning electron microscopy (SEM). [(*Evaluation Composite Restoration Posterior Teeth Proanthocyanidin Pretreatment Liner Using Fédération Dentaire Internationale Criteria: Split-Mouth Randomized Controlled Trial*, n.d.; Pranati et al., 2021; Sakthi 2021)](https://paperpile.com/c/57HK5Q/51no7+cGYlB+r1gcv) When examining a material's microscopic characteristics and its natural state, environmental scanning electron microscopy (ESEM) is used without any surface covering [(Egerton, 2016)](https://paperpile.com/c/57HK5Q/9KBwJ).In this study, the surface roughness was assessed using a laser microscope and a contact profilometer. Heimer Sturz et al. observed that the average Ra and Rz values were 0.277 μm and 0.547 μm, respectively, after polishing PEEK using 1,000-grit SiC paper. Nevertheless, these values were lowered to 0.073 μm and 0.148 μm by using a cotton buff to create a high-gloss finish using a 1-μm diamond paste [(Heimer et al., 2017)](https://paperpile.com/c/57HK5Q/hUYqD). Additionally, the same procedure was used to polish 50% inorganic nano-filled dimethylacrylate, yielding Ra and Sa values of 0.399 μm and 0.108 μm, respectively. This suggests that PEEK acquires a smoother surface when polished with diamond paste on a cotton buff alongside composite resin [(Kuhar & Funduk, 2005)](https://paperpile.com/c/57HK5Q/qU1VX).The choice of polishing materials and PEEK's hardness, which is either slightly greater than acrylic resin or equivalent, both have an impact on the polishing result. [(G. & Ganapathy, 2022; Kumar & Ramesh, 2021)](https://paperpile.com/c/57HK5Q/gxatD+fAt6O)) The researchers propose that, like the surface plastic flow attained in protocols S and A, the cutting action of diamond particles in the rubber point reduces the surface imperfections of PEEK. However, evaluating the "silky shine" and "aqua blue paste" in these procedures for their polishing impact based on material hardness is difficult because of their liquid/paste shape as well as undetermined hardness qualities [(Rao et al., 2015)](https://paperpile.com/c/57HK5Q/WiOhf).It is clear from the study's observations and findings that PEEK can be polished to produce a sufficiently smooth surface for use in dental prosthesis. For chairside use, a single-step polishing strategy is advised to save time and money, even if a multi-step protocol would produce an even smoother surface [(Pala et al., 2016)](https://paperpile.com/c/57HK5Q/iypP0).Based on the current investigation, color was measured using colorimeter. The device's instrumental reliability was proven by numerous studies [(*Effect of Artificially Accelerated Ageing and Different Mouth Rinses on Color Stability of Veneered PEEK Crowns*, n.d.; Porojan et al., 2021; Topcu et al., 2009)](https://paperpile.com/c/57HK5Q/2M5ZP+kfAn8+NCBbe). It is not possible to quantify transparent composites' color accurately using an opaque standard for evaluation, and there is a chance that bias will be introduced into the results. Still, a lot of studies have employed this methodology. Since white background has been approved and widely used, it was chosen for the current investigation [(Papathanasiou et al., 2022)](https://paperpile.com/c/57HK5Q/Bnalm). Ardu et al., on the other hand, discovered that black backgrounds worked better than grey and white backdrops. It is crucial to distinguish between the color difference that is statistically accepted and the color perception that human eyes can perceive. For this reason, it is established that ΔE values below 1.1 cannot be perceived by human eyes, and values beyond 3.3 are deemed clinically inappropriate [(Ardu et al., 2010)](https://paperpile.com/c/57HK5Q/Ag1ZV).The present study is one of its kind of study to assess the efficacy of chairside polishing kit. One of the main limitation of the study is it did not compare various polishing kits and techniques available in the market for PEEK. It is necessary to conduct more in vivo research to improve correlation with the clinical context.

# Conclusion

During the actual polishing process, it is important to take certain precautions. These include minimizing frictional resistance, preventing significant temperature changes on the material surface, avoiding splattering of the polishing agent, and ensuring easy removal of the agent post-polishing to prevent bacterial adherence. In summary, the use of the Shofu Super Snap series resulted in a clinically acceptable surface roughness for PEEK, demonstrating effective polishing and making it a viable chairside option. Also in the aspect of colour stability, distilled water resulted in the minimum and coffee resulted in maximum colour stability.

# References

1. Almatrafi, T. A., Almohaimeed, H. M., Chakravarthi, S., Amin, A. H., Jafer, A., & Akhavan-Sigari, R. (2024). Reducing metastasis ability of gastric cancer cell line by targeting MMP16 using miR-193a-5p and 5-FU. Advances in Medical Sciences, 69(2), 463-473.
2. [Abhay, S. S., Ganapathy, D., Veeraiyan, D. N., Ariga, P., Heboyan, A., Amornvit, P., Rokaya, D., & Srimaneepong, V. (2021). Wear Resistance, Color Stability and Displacement Resistance of Milled PEEK Crowns Compared to Zirconia Crowns under Stimulated Chewing and High-Performance Aging. *Polymers*, *13*(21). https://doi.org/](http://paperpile.com/b/57HK5Q/EuZQ5)[10.3390/polym13213761](http://dx.doi.org/10.3390/polym13213761)
3. [Ajay, R., JafarAbdulla, M. U., Sivakumar, J. S., Baburajan, K., Rakshagan, V., & Eyeswarya, J. (2023). Dental alloy adhesive primers and bond strength at alloy-resin interface: A systematic review and meta-analyses. *The Journal of Contemporary Dental Practice*, *24*(8), 521–544. https://doi.org/](http://paperpile.com/b/57HK5Q/3KKcS)[10.5005/jp-journals-10024-3514](http://dx.doi.org/10.5005/jp-journals-10024-3514)
4. [Akay, C., & Ersöz, M. B. (2020). PEEK in dentistry, properties and application areas. *International Dental Research*.](http://paperpile.com/b/57HK5Q/zlmpc) <https://www.dental-research.com/idr/article/view/188>
5. [Alsilani, R. S., Sherif, R. M., & Elkhodary, N. A. (2022). Evaluation of colour stability and surface roughness of three CAD/CAM materials (IPS e. max, Vita Enamic, and PEEK) after immersion in two beverage …. *Int J Appl Dent Sci*.](http://paperpile.com/b/57HK5Q/64Uvp) <https://www.researchgate.net/profile/Rana-Alsilani/publication/359202013_Evaluation_of_colour_stability_and_surface_roughness_of_three_CADCAM_materials_IPS_emax_Vita_Enamic_and_PEEK_after_immersion_in_two_beverage_solutions_An_in_vitro_study/links/62309a5f069a350c8b8fa0e8/Evaluation-of-colour-stability-and-surface-roughness-of-three-CAD-CAM-materials-IPS-emax-Vita-Enamic-and-PEEK-after-immersion-in-two-beverage-solutions-An-in-vitro-study.pdf>
6. [Ardu, S., Braut, V., Gutemberg, D., Krejci, I., Dietschi, D., & Feilzer, A. J. (2010). A long-term laboratory test on staining susceptibility of esthetic composite resin materials. *Quintessence International* , *41*(8), 695–702.](http://paperpile.com/b/57HK5Q/Ag1ZV) <https://www.ncbi.nlm.nih.gov/pubmed/20657860>
7. [Bathala, L., Majeti, V., Rachuri, N., Singh, N., & Gedela, S. (2019). The Role of Polyether Ether Ketone (Peek) in Dentistry - A Review. *Journal of Medicine and Life*, *12*(1), 5–9. https://doi.org/](http://paperpile.com/b/57HK5Q/GQfkq)[10.25122/jml-2019-0003](http://dx.doi.org/10.25122/jml-2019-0003)
8. [Bürgers, R., Gerlach, T., Hahnel, S., Schwarz, F., Handel, G., & Gosau, M. (2010). In vivo and in vitro biofilm formation on two different titanium implant surfaces. *Clinical Oral Implants Research*, *21*(2), 156–164. https://doi.org/](http://paperpile.com/b/57HK5Q/HNsWB)[10.1111/j.1600-0501.2009.01815.x](http://dx.doi.org/10.1111/j.1600-0501.2009.01815.x)
9. [Choi, M.-S., Lee, Y.-K., Lim, B.-S., Rhee, S.-H., & Yang, H.-C. (2005). Changes in surface characteristics of dental resin composites after polishing. *Journal of Materials Science. Materials in Medicine*, *16*(4), 347–353. https://doi.org/](http://paperpile.com/b/57HK5Q/Xd4VL)[10.1007/s10856-005-0634-9](http://dx.doi.org/10.1007/s10856-005-0634-9)
10. [Chokkattu, J. J., Mary, D. J., Shanmugam, R., & Neeharika, S. (2023). Evaluation clove ginger-mediated titanium oxide nanoparticles-based dental varnish against Streptococcus mutans Lactobacillus Species: vitro study. *World J Dent*, *14*(3), 233–237.](http://paperpile.com/b/57HK5Q/sUkxk)
11. [Dharman, S., Maragathavalli, G., Shanmugam, R., & Shanmugasundaram, K. (2023). Curcumin mediated gold nanoparticles analysis its antioxidant, anti-inflammatory, antimicrobial activity against oral pathogens. *Pesquisa Brasileira Em Odontopediatria E Clínica Integrada*, *23*.](http://paperpile.com/b/57HK5Q/8PUZK)
12. [Dobes, J., Leal, J. E. S., Profeta, J., de Sousa, M. M., Neto, F. P. L., Piratelli-Filho, A., & Arencibia, R. V. (2017). Effect of mechanical vibration on Ra, Rq, Rz, and Rt roughness parameters. *International Journal of Advanced Manufacturing Technology*, *92*(1-4), 393–406. https://doi.org/](http://paperpile.com/b/57HK5Q/YlULq)[10.1007/s00170-017-0137-0](http://dx.doi.org/10.1007/s00170-017-0137-0)
13. [*Effect of artificially accelerated ageing and different mouth rinses on color stability of veneered PEEK crowns*. (n.d.).](http://paperpile.com/b/57HK5Q/NCBbe) <https://journals.ekb.eg/article_143982.html>
14. [Egerton, R. F. (2016). *Physical Principles of Electron Microscopy: An Introduction to TEM, SEM, and AEM*. Springer.](http://paperpile.com/b/57HK5Q/9KBwJ) <https://play.google.com/store/books/details?id=HhWfDAAAQBAJ>
15. [*Evaluation Composite Restoration Posterior Teeth Proanthocyanidin Pretreatment Liner Using Fédération Dentaire Internationale Criteria: Split-mouth Randomized Controlled Trial*. (n.d.).](http://paperpile.com/b/57HK5Q/r1gcv)
16. [G., K. E. V., & Ganapathy, D. (2022). Operator errors in failed composite restoration-A review. *Int J Dent Oral Sci*, *8*(7), 2941–2944.](http://paperpile.com/b/57HK5Q/fAt6O) <https://www.academia.edu/download/73121996/IJDOS_2377_8075_08_702.pdf>
17. [Gungor, H., Gundogdu, M., & Yesil Duymus, Z. (2014). Investigation of the effect of different polishing techniques on the surface roughness of denture base and repair materials. *The Journal of Prosthetic Dentistry*, *112*(5), 1271–1277. https://doi.org/](http://paperpile.com/b/57HK5Q/fYHK4)[10.1016/j.prosdent.2014.03.023](http://dx.doi.org/10.1016/j.prosdent.2014.03.023)
18. [Heimer, S., Schmidlin, P. R., Roos, M., & Stawarczyk, B. (2017). Surface properties of polyetheretherketone after different laboratory and chairside polishing protocols. *The Journal of Prosthetic Dentistry*, *117*(3), 419–425. https://doi.org/](http://paperpile.com/b/57HK5Q/hUYqD)[10.1016/j.prosdent.2016.06.016](http://dx.doi.org/10.1016/j.prosdent.2016.06.016)
19. [Ishida, Y., Miura, D., & Shinya, A. (2023). Influence of toothbrush abrasion on the surface characteristics of CAD/CAM composite resin blocks with shade gradations. *Dental Materials Journal*, *42*(2), 193–198. https://doi.org/](http://paperpile.com/b/57HK5Q/mnUHN)[10.4012/dmj.2022-174](http://dx.doi.org/10.4012/dmj.2022-174)
20. [Jones, C. S., Billington, R. W., & Pearson, G. J. (2004). The in vivo perception of roughness of restorations. *British Dental Journal*, *196*(1), 42–45; discussion 31. https://doi.org/](http://paperpile.com/b/57HK5Q/ZtTNU)[10.1038/sj.bdj.4810881](http://dx.doi.org/10.1038/sj.bdj.4810881)
21. [Kasabwala, H., Nallaswamy, D., Subhashree, R., & Ahmed, N. (2021). Evaluation Of Overall Marginal Accuracy Of DMLS Copings Fabricated Using 3 Different DMLS Printing Machines. *Int J Dentistry Oral Sci*, *8*(7), 3335–3340.](http://paperpile.com/b/57HK5Q/zIeaR) <https://www.academia.edu/download/73133070/IJDOS_2377_8075_08_7085.pdf>
22. [Keerthana, T., & Ramesh, S. (2021). Knowledge, attitude and practice survey on awareness of the association between diet and dental erosion. *International Journal of Dentistry and Oral Science*, *8*(2), 1533–1540.](http://paperpile.com/b/57HK5Q/rBeTZ) <https://www.academia.edu/download/72505812/IJDOS_2377_8075_08_2026.pdf>
23. [Khurshid, Z., Nedumgottil, B. M., Ali, R. M. M., Bencharit, S., & Najeeb, S. (2022). Insufficient Evidence to Ascertain the Long-Term Survival of PEEK Dental Prostheses: A Systematic Review of Clinical Studies. *Polymers*, *14*(12). https://doi.org/](http://paperpile.com/b/57HK5Q/UelCm)[10.3390/polym14122441](http://dx.doi.org/10.3390/polym14122441)
24. [Kuhar, M., & Funduk, N. (2005). Effects of polishing techniques on the surface roughness of acrylic denture base resins. *The Journal of Prosthetic Dentistry*, *93*(1), 76–85. https://doi.org/](http://paperpile.com/b/57HK5Q/qU1VX)[10.1016/j.prosdent.2004.10.002](http://dx.doi.org/10.1016/j.prosdent.2004.10.002)
25. [Kumar, I. L., & Ramesh, S. (2021). Knowledge, Attitude and Practices (KAP) survey of shade selection for indirect veneers. *Int J Dent Oral Sci*, *26*, 2856–2864.](http://paperpile.com/b/57HK5Q/gxatD) <https://www.researchgate.net/profile/Sindhu-Ramesh/publication/353259903_Knowledge_Attitude_And_Practices_KAP_Survey_Of_Shade_Selection_For_Indirect_Veneers/links/60efe4d60859317dbde2f353/Knowledge-Attitude-And-Practices-KAP-Survey-Of-Shade-Selection-For-Indirect-Veneers.pdf>
26. [Kurahashi, K., Matsuda, T., Ishida, Y., & Ichikawa, T. (2020). Effect of polishing protocols on the surface roughness of polyetheretherketone. *Journal of Oral Science*, *62*(1), 40–42. https://doi.org/](http://paperpile.com/b/57HK5Q/bJ6Cz)[10.2334/josnusd.18-0473](http://dx.doi.org/10.2334/josnusd.18-0473)
27. [Mizutani, K., Takamizawa, T., Ishii, R., Shibasaki, S., Kurokawa, H., Suzuki, M., Tsujimoto, A., & Miyazaki, M. (2021). Flexural Properties and Polished Surface Characteristics of a Structural Colored Resin Composite. *Operative Dentistry*, *46*(3), E117–E131. https://doi.org/](http://paperpile.com/b/57HK5Q/6yYUm)[10.2341/20-154-L](http://dx.doi.org/10.2341/20-154-L)
28. [Murugesan, A. (2021). Saravana Dinesh SP evaluation of shear bond strength of ceramic brackets with two different base designs: An in-vitro study. *Int J Dentistry Oral Sci*.](http://paperpile.com/b/57HK5Q/EpmNL) <https://www.academia.edu/download/72981941/IJDOS_2377_8075_08_304.pdf>
29. [Ojha, N., Kumar, S., Ramesh, M. R., Balan, A. S. S., & Doddamani, M. (2023). A comprehensive characterization of 3D printable poly ether ketone ketone. *Journal of the Mechanical Behavior of Biomedical Materials*, *150*, 106243. https://doi.org/](http://paperpile.com/b/57HK5Q/Nbk39)[10.1016/j.jmbbm.2023.106243](http://dx.doi.org/10.1016/j.jmbbm.2023.106243)
30. [Padarthi, L. C., Anumula, L., Chinni, S. K., Sannapureddy, S., & Govula, K. (2023). Evaluation Composite Restoration Posterior Teeth Proanthocyanidin Pretreatment Liner Using Fédération Dentaire Internationale Criteria: Split-mouth Randomized Controlled Trial. *International Journal Prosthodontics Restorative Dentistry*, *13*(4), 191–200.](http://paperpile.com/b/57HK5Q/zlNhc)
31. [Pala, K., Tekçe, N., Tuncer, S., Serim, M. E., & Demirci, M. (2016). Evaluation of the surface hardness, roughness, gloss and color of composites after different finishing/polishing treatments and thermocycling using a multitechnique approach. *Dental Materials Journal*, *35*(2), 278–289. https://doi.org/](http://paperpile.com/b/57HK5Q/iypP0)[10.4012/dmj.2015-260](http://dx.doi.org/10.4012/dmj.2015-260)
32. [Panayotov, I. V., Orti, V., Cuisinier, F., & Yachouh, J. (2016). Polyetheretherketone (PEEK) for medical applications. *Journal of Materials Science. Materials in Medicine*, *27*(7), 118. https://doi.org/](http://paperpile.com/b/57HK5Q/djL9M)[10.1007/s10856-016-5731-4](http://dx.doi.org/10.1007/s10856-016-5731-4)
33. [Papathanasiou, I., Papavasiliou, G., Kamposiora, P., & Zoidis, P. (2022). Effect of Staining Solutions on Color Stability, Gloss and Surface Roughness of Removable Partial Dental Prosthetic Polymers. *Journal of Prosthodontics: Official Journal of the American College of Prosthodontists*, *31*(1), 65–71. https://doi.org/](http://paperpile.com/b/57HK5Q/Bnalm)[10.1111/jopr.13360](http://dx.doi.org/10.1111/jopr.13360)
34. [Pietrokovski, Y., Zeituni, D., Schwartz, A., & Beyth, N. (2022). Comparison of Different Finishing and Polishing Systems on Surface Roughness and Bacterial Adhesion of Resin Composite. *Materials*, *15*(21). https://doi.org/](http://paperpile.com/b/57HK5Q/co5Uo)[10.3390/ma15217415](http://dx.doi.org/10.3390/ma15217415)
35. [Porojan, L., Toma, F. R., Vasiliu, R. D., Topală, F.-I., Porojan, S. D., & Matichescu, A. (2021). Optical Properties and Color Stability of Dental PEEK Related to Artificial Ageing and Staining. *Polymers*, *13*(23). https://doi.org/](http://paperpile.com/b/57HK5Q/kfAn8)[10.3390/polym13234102](http://dx.doi.org/10.3390/polym13234102)
36. [Pranati, T., Ranjan, M., & Sandeep, A. H. (2021). Marginal adaptability custom made cast post made different techniques-a literature review. *Int J Dentistry Oral Sci*, *8*(8), 3954–3959.](http://paperpile.com/b/57HK5Q/51no7)
37. [Rajeshkumar, S., & Lakshmi, T. (2021). Biomedical potential of zinc oxide nanoparticles synthesized using plant extracts. *Int J Dent Oral Sci*, *8*, 4160–4163.](http://paperpile.com/b/57HK5Q/8hksu) <https://www.academia.edu/download/73182974/IJDOS_2377_8075_08_8120.pdf>
38. [Ramakrishnan, M., Shanmugam, R., Neeharika, S., Chokkattu, J. J., Thangavelu, L., & Khanna, N. (2023). Anti-inflammatory activity and cytotoxic effect of ginger and Rosemary-mediated titanium oxide nanoparticles-based dental varnish. *World Journal of Dentistry*, *14*(9), 761–765. https://doi.org/](http://paperpile.com/b/57HK5Q/iITP3)[10.5005/jp-journals-10015-2299](http://dx.doi.org/10.5005/jp-journals-10015-2299)
39. [Rao, D. C., Kalavathy, N., Mohammad, H. S., Hariprasad, A., & Kumar, C. R. (2015). Evaluation of the surface roughness of three heat-cured acrylic denture base resins with different conventional lathe polishing techniques: A comparative study. *Journal of Indian Prosthodontic Society*, *15*(4), 374–380. https://doi.org/](http://paperpile.com/b/57HK5Q/WiOhf)[10.4103/0972-4052.164910](http://dx.doi.org/10.4103/0972-4052.164910)
40. Saadh, M. J., Rasulova, I., Khalil, M., Farahim, F., Sârbu, I., Ciongradi, C. I. (2024). Natural killer cell-mediated immune surveillance in cancer: Role of tumor microenvironment. Pathology-Research and Practice, 254, 155120.
41. [Sakthi, S., (2021). Thymus vulgaris mediated selenium nanoparticles, characterization and its antimicrobial activity - an in vitro study. *International Journal of Dentistry and Oral Science*, 3516–3521. https://doi.org/](http://paperpile.com/b/57HK5Q/cGYlB)[10.19070/2377-8075-21000718](http://dx.doi.org/10.19070/2377-8075-21000718)
42. [Sarac, D., Sarac, Y. S., Kulunk, S., Ural, C., & Kulunk, T. (2006). The effect of polishing techniques on the surface roughness and color change of composite resins. *The Journal of Prosthetic Dentistry*, *96*(1), 33–40. https://doi.org/](http://paperpile.com/b/57HK5Q/fnTAR)[10.1016/j.prosdent.2006.04.012](http://dx.doi.org/10.1016/j.prosdent.2006.04.012)
43. [Shenoy, N. D., & Maiti, S. (2023). Evaluation marginal fit CAD/CAM crowns using CBCT digital scanners. *Annals Dental Specialty*, *11*(3-2023), 37–44.](http://paperpile.com/b/57HK5Q/NkMdd)
44. [Sindhu, J. S., Maiti, S., & Nallaswamy, D. (2023). Comparative analysis on efficiency and accuracy of parallel confocal microscopy and three-dimensional in motion video with triangulation technology-based intraoral scanner under influence of moisture and mouth opening - A crossover clinical trial. *Journal of Indian Prosthodontic Society*, *23*(3), 234–243. https://doi.org/](http://paperpile.com/b/57HK5Q/kzYR8)[10.4103/jips.jips\_65\_23](http://dx.doi.org/10.4103/jips.jips_65_23)
45. [Sindhu, S., Maiti, S., & Nallaswamy, D. (2023). Factors affecting accuracy intraoral scanners-a systematic review. *Annals Dental Specialty*, *11*(1-2023), 40–52.](http://paperpile.com/b/57HK5Q/vepKX)
46. [Sreenivasagan, S., Subramanian, A. K., Mohanraj, K. G., & Kumar, R. S. (2023). Assessment of toxicity of Green Synthesized Silver Nanoparticle-coated Titanium Mini-implants with Uncoated Mini-implants: Comparison in an Animal Model Study. *The Journal of Contemporary Dental Practice*, *24*(12), 944–950. https://doi.org/](http://paperpile.com/b/57HK5Q/iWq7a)[10.5005/jp-journals-10024-3577](http://dx.doi.org/10.5005/jp-journals-10024-3577)
47. [Sturz, C. R. C., Faber, F.-J., Scheer, M., Rothamel, D., & Neugebauer, J. (2015). Effects of various chair-side surface treatment methods on dental restorative materials with respect to contact angles and surface roughness. *Dental Materials Journal*, *34*(6), 796–813. https://doi.org/](http://paperpile.com/b/57HK5Q/USm55)[10.4012/dmj.2014-098](http://dx.doi.org/10.4012/dmj.2014-098)
48. [Subramanian, E., Ravindran, V., & Jeevanandan, G. (2021). Comparison of amount of tooth reduction in primary first molar for stainless steel, zirconia and fibre-glass crowns–in-vitro study. *International Journal of Dentistry and Oral Science*, *8*(7), 3427–3430.](http://paperpile.com/b/57HK5Q/1qzwj) <https://www.academia.edu/download/73139190/IJDOS_2377_8075_08_7103.pdf>
49. [Su, Q., Qiao, Y., Xiao, Y., Yang, S., Wu, H., Li, J., He, X., Hu, X., Yang, H., & Yong, X. (2023). Research progress of 3D printed poly (ether ether ketone) in the reconstruction of craniomaxillofacial bone defects. *Frontiers in Bioengineering and Biotechnology*, *11*, 1259696. https://doi.org/](http://paperpile.com/b/57HK5Q/Pd6rn)[10.3389/fbioe.2023.1259696](http://dx.doi.org/10.3389/fbioe.2023.1259696)
50. [Tiwari, A., & Jain, R. K. (2021). The effect of motivational and reminder therapy on the compliance of patients wearing fixed appliances. *Int J Dent Oral Sci*, *8*(7), 3303–3305.](http://paperpile.com/b/57HK5Q/PVxF6) <https://www.academia.edu/download/73131909/IJDOS_2377_8075_08_7079.pdf>
51. [Topcu, F. T., Sahinkesen, G., Yamanel, K., Erdemir, U., Oktay, E. A., & Ersahan, S. (2009). Influence of different drinks on the colour stability of dental resin composites. *European Journal of Dentistry*, *3*(1), 50–56.](http://paperpile.com/b/57HK5Q/2M5ZP) <https://www.ncbi.nlm.nih.gov/pubmed/19262731>
52. [Varghese, R., Maliael, M., & Subramanian, A. (2023). Antibacterial activity of nanoparticle-coated orthodontic archwires: A systematic review. *Journal of International Oral Health: JIOH*, *15*(1), 1. https://doi.org/](http://paperpile.com/b/57HK5Q/ClQhg)[10.4103/jioh.jioh\_152\_22](http://dx.doi.org/10.4103/jioh.jioh_152_22)