ORIGINAL ARTICLE

Evaluation of the mechanical properties of Composite Resins Treated with Royal Jelly, Glycerin, and Panavia Oxyguard used as Oxygen-Inhibiting Agents – an *in vitro* study

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Abstract

Aim: To compare and contrast the efficacy of Royal Jelly, Glycerine, and Panavia Oxyguard as oxygen-inhibitors with respect to degree of conversion, surface hardness, and surface irregularity of composite resins. **Methods:** With the selection of such one resin composite having the name Tetric-N-Ceram, A2 shade, thirty discs of composite was fabricated. In these thirty discs, oxygen- inhibiting agents were applied before light curing for the three groups (10 each) as follows: group A-glycerine, group B-Panavia Oxyguard, and group C-Royal Jelly. Surface hardness was measured by using a Vickers micro-hardness tester, surface roughness was assessed through a 3D profilometer, and degree of conversion was calculated by Fourier-transform infrared (FTIR) spectroscopy. **Results:** Highest surface hardness (mean: 58.34 VHN) was revealed in specimens treated with Royal Jelly, followed by Glycerine (37.77 VHN) and then Panavia Oxyguard (30.02 VHN). Royal Jelly also exhibited superior performance in aspects of surface characteristics and degree of conversion again showing better polymerization of the natural agents than the synthetic ones. **Conclusion:** Royal Jelly shown to be an effective oxygen-inhibitor in that it exhibits improved polymerization, surface hardness, and total quality of surface of the composite resins when compared with Glycerine and Panavia Oxyguard. The bioactive features that it possesses also give credence to its potential as a natural alternative in restorative dentistry.

Key words: Composite, degree of conversion, Fourier-transform infrared spectroscopy, oxygen inhibition, royal jelly, surface hardness

INTRODUCTION

The oxygen-inhibition layer (OIL) is a peripheral uncured resin coating that is formed due to the reactions linking atmospheric oxygen with free radicals produced due to the polymerization of resin composites. The degree of conversion (DC), surface hardness, and resistance to abrasion of composites are adversely affected by this phenomenon.[1,2] Even during optimal curing, the oxygen at the surface does not allow full polymerization, leading to weakened physical qualities and increased vulnerability to staining and plaque build-up.[3] Various techniques are being used to address oxygen inhibition, including the application of oxygen-inhibiting gel over resin composites. Agents such as Panavia Oxyguard and Glycerin are used to create a physical barrier over its surface, allowing for increased polymerization and improved resin integrity.[4] While Panavia Oxyguard is commercially available and is specifically designed for this purpose, Glycerin demonstrates satisfactory efficacy in enhancing the DC of composites.[5] Natural biomaterials are gaining popularity as alternatives due to their inherent bioactive and biocompatible nature. Royal Jelly (RJ)

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is an apiarian secretion rich in various proteins, poly-peptides, flavonoids, fatty acids, and some trace elements, such as zinc, copper, and manganese.[5,6] It has shown potent antioxidant, anti-inflammatory, and antimicrobial properties, which potentially improve the clinical performance of dental composites.[7,8] Moreover, studies have demonstrated its superoxide dismutase activity and radical oxygen scavenging potential, suggesting that RJ might act as a physical barrier and also chemically stabilize the polymerization process.[9] Surface hardness and surface roughness are important indicators of the composite's quality and longevity. Increased surface hardness is associated with enhanced polymerization, while reduced roughness is associated with reduced plaque accumulation and improved appearance,[10,11] Given the emerging evidence on the benefits of RJ, evaluation of its potential as an oxygen-inhibitor could provide a new strategy in restorative dentistry. This *in vitro* study thus aims to compare the efficacy of RJ with Panavia Oxyguard and Glycerin in reducing the OIL and enhancing the surface properties of nano hybrid composite resin.

MATERIALS AND METHODS

This study was conducted following ethical principles and was duly registered under the Institutional Ethical Committee with the reference number SRB/SDC/2306/25/ENDO/069.

Royally Jelly extraction

RJ was freshly obtained from *Apis mellifera* worker bees. It was extracted using a sterile spatula from queen larval cells between the 3rd and 4th day of larval development. The jelly was immediately stored at 4°C in light-proof containers to preserve its bioactive compounds. Before application on composite specimens, RJ was equilibrated to room temperature and applied in a thin layer using a micro-brush to ensure uniform distribution.

Sample preparation

A total of 30 standardized composite resin discs were fabricated using a nano hybrid resin composite material (Tetric-N-Ceram, Shade A2, IvoclarVivadent, Liechtenstein). Each disc measured 5 mm in diameter and 2 mm in thickness. The composite was incrementally packed into cylindrical stainless steel molds, and a Mylar strip was placed on the top and bottom surfaces to achieve a flat finish. The material was light-cured for 20 s using a calibrated LED curing apparatus (Bluephase N, Ivoclar Viva dent; output intensity: 1,200 mW/cm^2), according to the manufacturer's guidelines [Figure 1].

Group allocation

The 30 specimens were split into three groups at random ($n = 10$ per group) according to the oxygen-inhibiting chemical that was used:

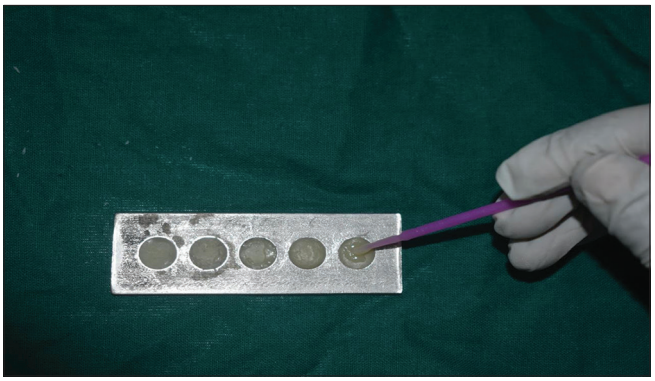


Figure 1: Sample preparation using 10 × 2 mm metallic molds

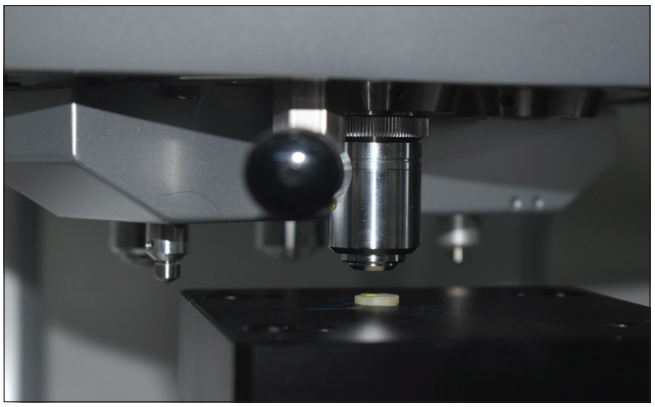


Figure 2: Surface hardness assessment of prepared samples using the Vickers hardness tester

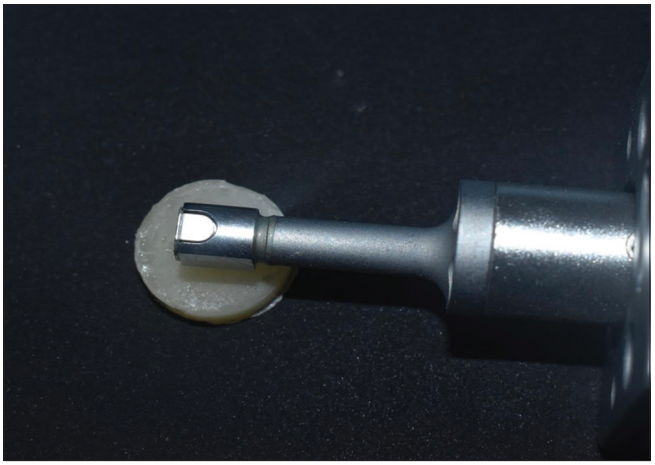
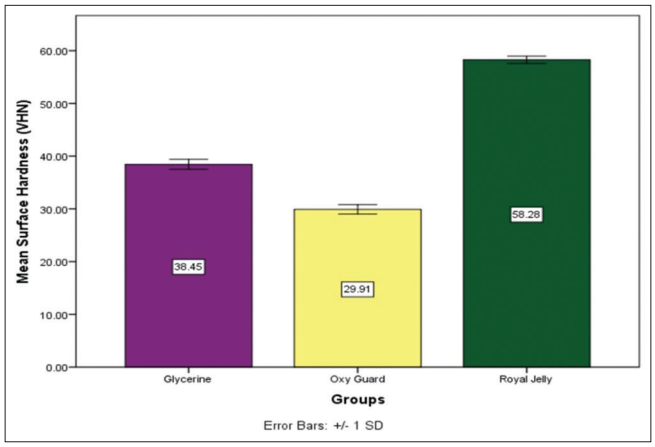


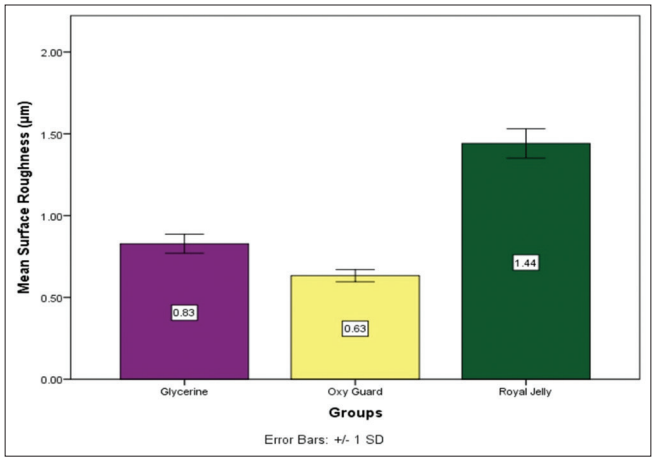
Figure 3: Surface roughness assessment using surface profilometer

Group A: Glycerin (control)
Group B: Panavia Oxyguard II (Kuraray, Japan)
Group C: RJ (freshly harvested, unprocessed).

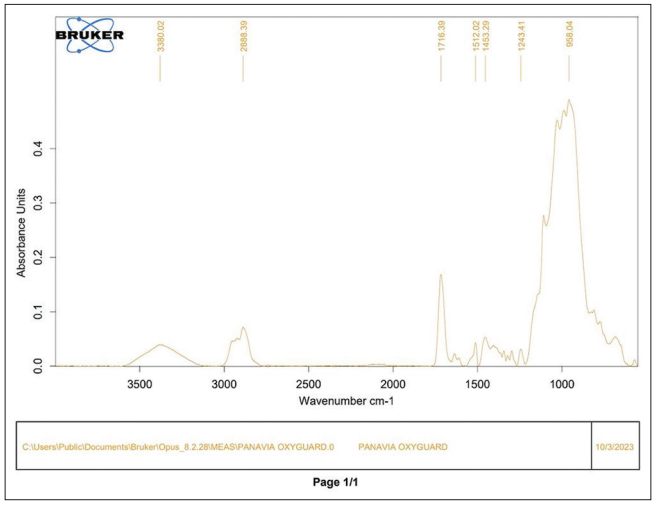
Each agent was coated over the top surface of the composites before light-curing. After curing, the agents were rinsed off with distilled water, and the specimens were stored in artificial saliva at 37°C for 24 h to simulate intraoral conditions.



Graph 1: Comparative evaluation of the mean surface hardness of Royal Jelly, Glycerin, and Oxyguard



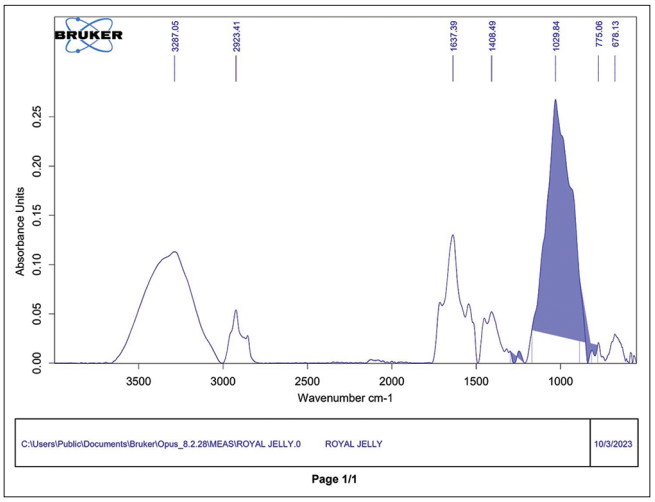
Graph 2: Comparative evaluation of the mean surface roughness of Royal Jelly, Glycerin, and Oxyguard



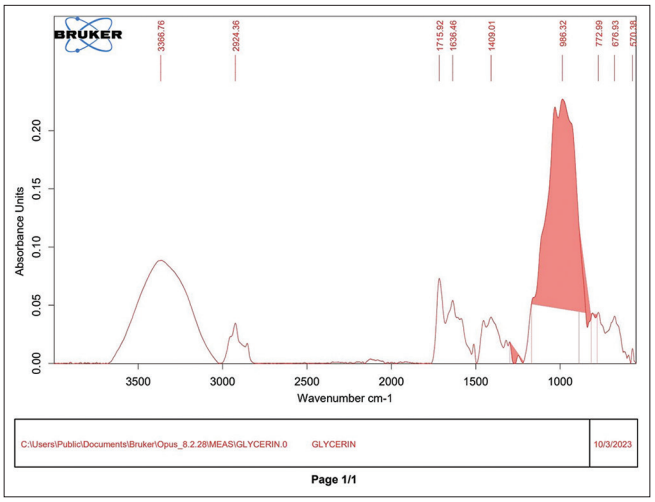
Graph 3: Fourier-transform infrared spectrum of Panavia Oxyguard-treated composite disc

Surface hardness evaluation

Surface microhardness was assessed using a Vickers microhardness tester (Shimadzu HMV-G Series, Japan).



Graph 4: Fourier-transform infrared spectrum of Royal Jelly-treated composite disc



Graph 5: Fourier-transform infrared spectrum of glycerin-treated composite disc

Three indentations were made on each specimen using a 100 g load for 15 s, and the average hardness value (Vickers Hardness Number - VHN) was calculated for each sample [Figure 2].

Surface roughness analysis

Surface roughness (Ra) was measured using a non-contact 3D optical profilometer (Bruker Contour GT-K). Each specimen was scanned at three distinct regions, and the average surface roughness was recorded in micrometers (µm). Care was taken to avoid the edges of the disc during measurements [Figure 3].

DC by Fourier-transform infrared (FTIR) spectroscopy

To ascertain the DC of the composite resin in each group, FTIR spectroscopy was employed. A Bruker Alpha II FTIR

spectrometer was used to record the spectra, which ranged from 4000 to 400 cm^{-1}. The characteristic aliphatic C=C peak (~1637 cm^{-1}) and aromatic C–C peak (~1608 cm^{-1}) were used to calculate the DC using the following formula [Graphs 3-5]:[12]

$$DC(\%) = [1-(\frac{A_{aliphatic}}{A_{aromatic}})poly \div (\frac{A_{aliphatic}}{A_{aromatic}})unpoly] \times 100$$

RESULTS

Surface hardness

The Vickers microhardness test revealed statistically significant differences in surface hardness among the three groups. RJ (Group C) exhibited the highest mean surface hardness value (58.34 ± 1.25 VHN), followed by Glycerin (Group A) with 37.77 ± 1.10 VHN, and Panavia Oxyguard (Group B) showing the lowest value (30.02 ± 0.94 VHN). The difference between all three groups was statistically significant ($P < 0.05$), as confirmed by one-way analysis of variance (ANOVA) followed by Tukey's *post hoc* test.

These findings suggested that RJ contributed to enhanced polymerization at the surface level, likely due to both its barrier and antioxidant effects, leading to increased crosslinking and mechanical integrity [Table 1 and Graph 1].

Table 1: Descriptive statistics of surface hardness (VHN) and surface roughness (μm) of composite discs treated with different oxygen-inhibiting agents

Groups	Surface hardness (VHN)	Surface roughness (μm)
Glycerin		
Mean	38.4500	0.8280
Standard deviation	0.93948	0.05789
Oxyguard		
Mean	29.9080	0.6330
Standard deviation	0.89662	0.03713
Royal Jelly		
Mean	58.2780	1.4410
Standard deviation	0.70370	0.08975

Surface roughness

Surface roughness (Ra) values also demonstrated intergroup variation. RJ -treated specimens (Group C) exhibited a mean roughness of 1.40 ± 0.09 μm, which was slightly higher than Glycerin (0.89 ± 0.07 μm) and Panavia Oxyguard (0.63 ± 0.05 μm). Although roughness values increased in Group C, they remained within clinically acceptable limits and did not compromise the visual smoothness or gloss of the composite surface.

The increase in roughness with RJ may be attributed to its organic matrix interacting with the surface polymerization dynamics, possibly introducing minor surface irregularities despite deeper conversion [Table 2 and Graph 2].

DC (FTIR spectroscopy)

FTIR analysis revealed a reduction in the aliphatic C=C stretching peak (~1636–1637 cm^{-1}), indicating effective polymerization in all groups. However, the highest DC was

Table 2: Tukey's *post hoc* analysis comparing surface roughness (μm) and surface hardness (VHN) in composite discs treated with various oxygen inhibiting agents

Multiple comparisons							
Tukey HSD							
Dependent variable	(I) groups	(J) groups	Mean difference (I-J)	Standard error	Significance	95% confidence interval	
						Lower bound	Upper bound
Surface hardness (VHN)	Glycerin	Oxyguard	8.54200*	0.38138	0.000	7.5964	9.4876
		Royal Jelly	−19.82800*	0.38138	0.000	−20.7736	−18.8824
	Oxyguard	Glycerin	−8.54200*	0.38138	0.000	−9.4876	−7.5964
		Royal Jelly	−28.37000*	0.38138	0.000	−29.3156	−27.4244
	Royal Jelly	Glycerin	19.82800*	0.38138	0.000	18.8824	20.7736
		Oxyguard	28.37000*	0.38138	0.000	27.4244	29.3156
Surface roughness (μm)	Glycerin	Oxyguard	0.19500*	0.02919	0.000	0.1226	0.2674
		Royal Jelly	−0.61300*	0.02919	0.000	−0.6854	−0.5406
	Oxyguard	Glycerin	−0.19500*	0.02919	0.000	−0.2674	−0.1226
		Royal Jelly	−0.80800*	0.02919	0.000	−0.8804	−0.7356
	Royal Jelly	Glycerin	0.61300*	0.02919	0.000	0.5406	0.6854
		Oxyguard	0.80800*	0.02919	0.000	0.7356	0.8804

*. The mean difference is significant at the 0.05 level

observed in Group C (RJ), with a substantial decrease in the aliphatic-to-aromatic peak ratio compared to unpolymerized controls. Group A (Glycerin) showed moderate DC, whereas Group B (Panavia Oxyguard) exhibited the lowest conversion levels, consistent with the surface hardness data.

RJ's bioactive components, including flavonoids and antioxidant peptides, may be responsible for its higher conversion rate. These chemicals also probably helped stabilize radicals throughout the curing process.

Statistical analysis

One-way ANOVA was used to compare the means of the three groups. Tukey's *post hoc* test was used to assess intergroup significance in cases where statistically significant differences were discovered. $P < 0.05$ were regarded as statistically significant. IBM Statistical Package for the Social Sciences Statistics for Windows, Version 26.0 (Armonk, NY: IBM Corp.) was used to conduct the statistical study.

DISCUSSION

This study demonstrated and compared the efficacy of RJ, Panavia Oxyguard, and Glycerin as oxygen-inhibiting agents when applied over composite resins. The results of this study revealed that RJ had significantly improved the surface hardness and DC of the fabricated discs, suggesting its use as a bioactive alternative to conventional oxygen-inhibiting agents. The superior action of RJ could be attributed to its formulation of bioactive compounds, such as flavonoids, phenolic acids, 10-hydroxy-2-decenoic acid, and major RJ proteins, which are known to have strong antioxidant activity. These components have shown scavenging of free radicals that mimic superoxide dismutase activity, contributing to efficient polymerization by neutralizing reactive intermediates.[13] Notably, studies by Nagai and Inoue demonstrated that RJ exhibited comparable radical-scavenging capacity to Vitamin C and BHT, supporting its ability in radical-free polymerization.[14]

Surface hardness, which is an indicator of the degree of cross-linking in polymerized resin, was significantly higher in the RJ-treated group. This aligned with findings from Yang *et al*., who noted that antioxidant-rich environments facilitate deeper and more uniform polymerization of composite materials, improving mechanical integrity.[14,15] Moreover, a study by Munchow *et al*. showed a positive correlation between the DC and surface micro hardness, reinforcing the interpretation that RJ contributed to an improved polymer network structure.[11] In terms of surface roughness, although RJ resulted in slightly higher Ra values, they remained within acceptable clinical limits. This increase may be due to organic remnants from RJ or the interaction between resin components and proteinaceous compounds in the jelly. However, this is unlikely to compromise clinical performance, as finishing and polishing techniques can reduce surface irregularities effectively. In addition, RJ's well-documented antimicrobial effects against *Streptococcus mutans* and *Staphylococcus aureus* may counterbalance the impact of surface texture on biofilm formation.[16]

The antimicrobial properties of RJ have been attributed to compounds such as royalisin and jelleines, which have demonstrated efficacy against both Gram-positive and Gram-negative oral bacteria. For instance, research by Fontana *et al*. reported that RJ disrupted bacterial membranes and inhibited the growth of cariogenic pathogens, even at low concentrations.[7] In contrast, Panavia Oxyguard showed the lowest values for both surface hardness and DC. This may be due to the presence of opacifiers or reactive amine compounds that interfere with light transmission and free radical propagation. Glycerin performed moderately across all parameters, consistent with its role as a transparent physical barrier that does not chemically interact with the resin system.[7,17]

From a clinical perspective, the ability of RJ to support both biological and mechanical outcomes makes it a promising candidate for broader dental applications. Its anti-inflammatory effects – shown to reduce IL-6 and TNF-α expression – and its regenerative potential have been reported in periodontal and mucosal wound healing studies.[8,18] This dual functionality could be advantageous in aesthetic zones and subgingival restorations where both material and tissue compatibility are paramount. Although these *in vitro* results are promising, clinical translation requires caution. The natural variability of RJ, depending on source and seasonality, may influence consistency in performance. Future studies should explore standardized formulations and evaluate their impact on long-term mechanical stability, color retention, and biocompatibility under intraoral conditions.[18-21]

CONCLUSION

Within the limitations of this *in vitro* study, it can be concluded that RJ is an effective and biocompatible alternative to conventional oxygen-inhibiting agents such as Glycerin and Panavia Oxyguard in composite resin applications. Specimens treated with RJ demonstrated superior surface hardness and DC, indicating enhanced polymerization efficiency. While a slight increase in surface roughness was noted, it remained within clinically acceptable limits and is unlikely to compromise performance, especially considering RJ's inherent antimicrobial and anti-inflammatory properties.

The results suggest that RJ not only acts as a physical barrier to oxygen but may also play a biochemical role in stabilizing free radicals during polymerization, thereby improving the structural and biological quality of the composite. Its anti-inflammatory activity, promotion of tissue healing, and

potential for reducing bacterial colonization further enhance its value for esthetic and subgingival restorative procedures.

Future clinical trials and standardized formulation studies are recommended to validate these findings and explore the long-term effects of RJ on marginal adaptation, colour stability, and intraoral biocompatibility.

Declaration

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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