Polym. Korea, Vol. 45, No. 3, pp. 421-427 (2021)
https://doi.org/10.7317/pk.2021.45.3.421

ISSN 0379-153X(Print)
ISSN 2234-8077(Online)

TiO_2/PLCL 생분해성 고분자 복합체를 이용한 치아 미백 및 보호효과에 대한 연구

임진익†

단국대학교 화학공학과

(2020년 12월 10일 접수, 2021년 1월 30일 수정, 2021년 2월 8일 채택)

Tooth Whitening and Protecting Effect Using TiO_2/PLCL Biodegradable Polymer Composites

Jin Ik Lim†

Department of Chemical Engineering, College of Engineering, Dankook University,
Jukjeon-dong, Yongin-si, Gyeonggi-do 16890, Korea

(Received December 10, 2020; Revised January 30, 2021; Accepted February 8, 2021)

초록: 치아매니큐어에 적용하기 위한 베이스 레진으로 poly(*L*-lactide-*co*-*ε*-caprolactone)(PLCL)을 합성하였고, 락티드와 카프로락톤의 최적 비율을 결정하였다. TiO_2는 미백을 위한 안료로 적용되어졌으며, 최적의 TiO_2/PLCL 조성비를 위해 탄성회복률, 연필심 경도 측정, 색차계 시험, 접촉각 측정을 진행하였다. 이를 통해 PLCL을 위한 락티드와 카프로락톤의 최적비율은 50:50이였으며, TiO_2의 최적 비율은 10%임을 확인하였다. 세포독성 시험 결과 우수한 세포 부착 및 증식 효과를 확인하였고, 천연 치자색소를 이용하여 다양한 노란색 코팅제를 제조해 보았다. 본 연구결과 TiO_2/PLCL 복합체는 치아 미백 및 미용 매니큐어의 재료로 적합한 것으로 판단된다.

Abstract: Poly(*L*-lactide-*co*-*ε*-caprolactone) (PLCL) was synthesized, and this was mixed with TiO_2 for tooth manicure. A mechanical test was conducted using a tensile strength testing machine and pencil hardness tester; these tests indicated that the optimal molar ratio of lactide in PLCL was 50%. Differences in the surface structures of the films with respect to the hydrophobicity and the whitening effect were examined using a digital microscope, a contact angle meter, and colorimeter. The optimal ratio of TiO_2 for the composite was determined to be 10%. The composite coated glass plate yielded a good cell adhesion rate in fibroblasts. The TiO_2/PLCL composite manufactured by this simple method can be applied to implantable dental materials, used for tooth whitening, and as a protecting agent during tooth manicures.

Keywords: tooth manicure, whitening, protecting, poly(*L*-lactide-*co*-*ε*-caprolactone), titanium dioxide.

Introduction

Tooth whitening is a popular dental treatment that continues to grow with public demand for aesthetics. For hundred years, various researchers have studied whitening and bleaching materials. There are many reasons for tooth discoloration, such as personal habits, dental problems, or exposure to other substances.[1,2]

Nowadays, the main active ingredients in tooth whitening products are peroxides, such as hydrogen peroxide[3] and carbamide peroxide.[4] Although some peroxides, such as peroxy caproic acid (PAP),[5] were considered safer, hydrogen peroxide has been the most efficient ingredient of tooth whitening products. However, teeth's whitening by hydrogen peroxide is harmful to the oral mucosa and dentin because it causes oral mucosa burns and dentin allergies.[6,7]

Recently, coating resin composite materials, such as shellac, gum, and polyacrylates, have been explored mainly as tooth manicure materials in cases in which instantaneous aesthetic improvement of teeth is a priority. However, these materials have been reported to become unstable because of moisture, resulting in weak mechanical properties.[8-10] Various studies have been conducted to overcome this.[11,12]

In addition, there are other disadvantages, such as feeling of irritation because of the roughness of the coating surface, less glossiness, hypersensitivity, and re-coloration.[13,14]

In this study, poly(*L*-lactide-*co*-*ε*-caprolactone) (PLCL), a synthetic biodegradable polymer, was selected as the optimal base polymer for creating composites for tooth whitening with-

---

†To whom correspondence should be addressed.
limjinik@dankook.ac.kr, ORCID 0000-0003-4803-0455

out hydrogen peroxide.

In previous studies, synthetic biodegradable polymers, such as poly(lactic acid) (PLA), poly(glycolic acid) (PGA), poly (lactide-*co*-glycolide) (PLGA), poly(ε-caprolactone) (PCL), poly(glycolide-*co*-caprolactone) (PGCL), and PLCL were developed for vessel or cartilage tissue engineering.[15-17] Among these, PLCL with a molar ratio of 50:50 exhibited unique elasticity; hence, it was used as a tissue engineering scaffold to investigate the effect of mechanical stimulation on tissue regeneration.[18,19]

TiO_2 has been extensively researched over the last few decades because of its outstanding physicochemical properties. It possesses interesting optical, dielectric, and analytical properties that are exploited in industrial applications, such as pigments, filters, and catalyst supports.[20,21] In addition, it is generally used as a semiconductor because of its high photoactivity, low cost, high availability, and non-toxicity. White pigment is important in dental manicure. In this study, TiO_2, which is not toxic and is used as a food, was selected as a white pigment.

We postulate that the amorphous PLCL at a molar ratio of 50:50 can impart close-up characteristics and elastic properties for tooth whitening and protection in dental manicure.

Therefore, the objectives of this study were to i) determine the optimal molar ratio of PLCL for use as a tooth coating agent; ii) evaluate the whitening and protection efficiency of the TiO_2/PLCL composite; and iii) evaluate the cytotoxicity of the composite film on a fibroblast (NIH3T3).

Experimental

Materials. *L*-lactide (Purac Biochem, Birmingham, UK) was used to synthesize PLCL. Stannous octoate, ε-caprolactone, methanol, chloroform, ethyl acetate, and titanium dioxide (99 wt%) were purchased from Sigma-Aldrich (St. Louis, MO, USA). All chemicals were used without further purification, except ε-caprolactone.

PLCL (molar ratio: 70:30, 50:50, and 30:70; number-average molecular weight: 16×10^4, 15×10^4, and 14×10^4, respectively) was polymerized and analyzed using methods described elsewhere.[22]

Fabrication of PLCL Films and Solubility Tests. PLCLs of molar ratios 70:30, 50:50, and 30:70 were dissolved in 10% (w/v) chloroform, ethyl acetate, and dichloromethane by magnetic stirring at room temperature for 5 h. The remaining undissolved polymer was weighed. To form the film, resulting solutions of 100 mL as 10% (w/v) of each PLCL solution in chloroform were injected onto a Teflon plate ($200\times200\times3$ mm^3), dried at room temperature for 2 weeks, and vacuum dried for 48 h. The obtained film was washed with pure water for 1 h and then vacuum dried.

Measurement of Shear Bond Strength. The shear bond strength to dentin was measured as a function of the molar ratio (70:30, 50:50, and 30:70) of lactide and caprolactone to PLCL. To prepare a dentin surface with embedded acryl resin, freshly extracted human molar teeth were polished with 600 grit sand paper using a polishing machine (RotoPol-25; Struers, Ballerup, Denmark). Then, each 10% (w/v) PLCL solution in chloroform was mixed with 10% (w/v) TiO_2 and placed in a Teflon mold (diameter = 4 mm, height = 7 mm) laid on a polished dentin surface. After 2 weeks at 40 ºC, the mold was removed from the dried composite sample. The specimens were then immersed in distilled water at 37ºC for 24 h. The shear bond strength was measured using a universal testing machine.[23,24] The crosshead speed was set to 1 mm/min, and the load required to debone the specimen from the dentin was determined.

Fabrication of TiO_2/PLCL Composites according to TiO_2 Contents. 10% (w/v) of PLCL (50:50) solutions were mixed into the PLCL solution to obtain TiO_2 concentrations of 0, 5, 10, 15, 20, and 25% (w/v). As described in section 2.2. Films were formed from the mixtures by the aforementioned film casting method and stored at room temperature under vacuum until they were used.

Characterization of TiO_2/PLCL Composites. The TiO_2/PLCL composite films were dried at room temperature and the water contact angle (Phoenix 150; Surface Electro Optics, Seoul, Korea), surface morphology, and dispersion state of TiO_2 were observed. A digital microscope (digital microscope: A-2111; Dino-Lite, Taiwan) was used to observe the surface morphology and dispersion state of TiO_2.

To examine recovery from elongation, PLCL films ($200\times200\times1.5$ mm^3) were prepared from TiO_2 concentrations of 0, 5, 10, 15, 20, and 25%. The recovery test was carried out using a universal testing machine (Instron model 4467, Canton, MA, USA). A 10 N load cell with a crosshead speed of 10 mm/min (strain = 250%) was used. The recovery was calculated as Recovery (%) = $100-((L_2-L_0)/(L_1-L_0)\times100)$, where L_0, L_1, and L_2 indicate the original length, extended length, and final length, respectively, after releasing the stress. In addition, the elongation at break (%) was measured as the elongation length at the broken point.

The surface hardness of the TiO_2/PLCL composite film was determined by a hardness test using an Imoto IMC-1552 pencil scratch hardness tester according to the JIS K5600-5-4 standard (equivalent to ISO/DIS 15184).

Meanwhile, the color was measured according to the CIE LAB color scale relative to the standard illuminant D65 in the reflectance mode over a white background (CIE $L^*=94.3$, $a^*=-0.1$, and $b^*=-0.4$) on a spectrophotometer (Color-Eye 7000A, GretagMacbeth Instruments, New Windsor, NY, USA). The aperture size was 3 mm×8 mm. The measurements were repeated three times for each specimen.

The fabricated TiO_2/PLCL composites were applied to the upper tooth surface of human body with a sponge-type brush. Only the upper tooth was painted to compare the manicured part with the non-manicured part.

Cytotoxicity tests of the TiO_2/PLCL composite were performed using a previously described method.[25] For this, the TiO_2/PLCL composite films were pre-wetted with a medium [Dulbecco's modified Eagle's medium supplemented with 2 mM L-glutamine and 10% fetal bovine serum] and incubated at 37 °C in a 5% CO_2 environment. After 12 h, the medium was aspirated, and NIH3T3 cells (ATCC-L929, Manassas, VA, USA) were plated directly on each film in a 200 μL media suspension. The cell density was set at 3×10^4 cells per well. After another 1 h, 1800 μL medium was added to each well, and the initial adhesion and proliferation were quantified using a WST-8 assay.

To produce various yellow colors, gardenia yellow and TiO_2 were mixed in PLCL, as shown in Table 3. The film was prepared as described earlier, and the color analysis was carried out.

Results and Discussion

Mechanical Properties for Optimal Molar Ratio of PLCL. The results of the characterization of the synthesized PLCL (molar ratio: 70:30, 50:50, and 30:70) are shown in Table 1. No difference in solubility was observed in chloroform, ethyl acetate, or dichloromethane. Solvents are important in the application of biomaterials. Chloroform and dichloromethane have been reported as highly toxic and carcinogenic,[26,27] whereas ethyl acetate, a natural substance that is relatively less toxic, is usually used in food additives, perfume, and solvent for dental vanish as a Fluor protector (Ivoclar vivadent AG, Swiss).[28,29] Therefore, ethyl acetate was selected as the optimal solvent for dental manicure. The elastic recovery and elongation at break of the PLCL films were measured and results are shown in Table 1. A high elastic recovery and good elongation properties were observed in the PLCL film at a molar ratio of 50:50. Elastic recovery and elongation properties are important factors that determine the adhesion properties on the tooth surface for low impact strength and tough tensile properties.

Result of Shear Bond Strength. The shear bond strength values of the PLCLs at molar ratios of 70:30, 50:50, and 30:70 were measured. The PLCLs at a molar ratio of 50:50 showed more than 1.5-fold increase in the bond strength compared with the PLCLs at molar ratios of 30:70 and 70:30, as shown in Figure 1. The high bond strength of the specimens of the PLCLs at a molar ratio of 50:50 was because of the amorphous crystal structure of PLCL and the inherent stickiness and toughness on dentin. Meanwhile, lower bond strength was observed in the PLCLs at molar ratios of 70:30 and 30:70. This lower strength might have been because of the decreased impact strength due to the increased rigidity caused by the variation in the crystallization with changes in the molar ratio. Therefore, as shown in Table 1 and Figure 1, the 50:50 molar ratio is suitable for enhancing adhesive properties on the tooth; hence, it was prepared for further study.

Mechanical Properties of the TiO_2/PLCL Composites. The mechanical properties of the TiO_2/PLCL (50:50) composites with TiO_2 concentrations of 0, 5, 10, 15, 20, and 25% are shown in Table 2. Superior elastic recovery and elongation properties were observed in the TiO_2/PLCL composite at 10% and 15%; however, these were lower in the rest of the samples. In addition, a low hardness of 4 B was observed from the sur-

Table 1. Properties of Poly(*L*-lactide-*co*-ε-caprolactone) (PLCL) according to Molar Ratio (n=5, *$P<0.05$)

PLCL (lactide:caprolactone)	Solubility			Elastic recovery at 200% strain	Elongation at break (%)
	Chloroform	EA	Dichloromethane		
70:30	0	0	0	91±2*	450±4*
50:50	0	0	0	94±2*	1020±3*
30:70	0	0	0	86±3*	1100±5*

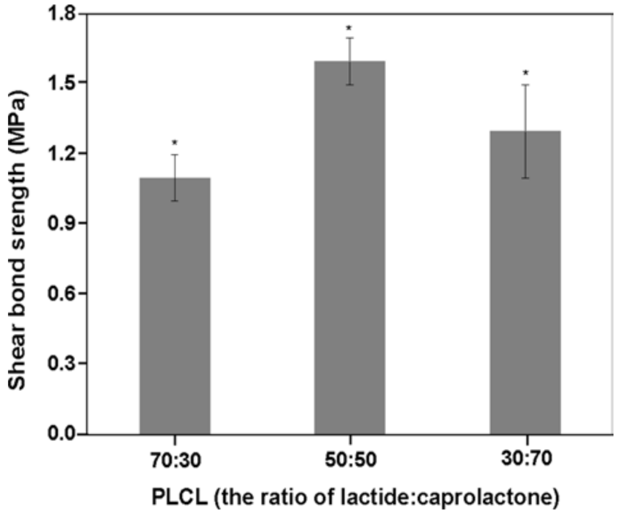

Figure 1. Shear bond strength of poly(*L*-lactide-*co*-*ε*-caprolactone) (PLCL) according to molar ratio (n=5, $^*P<0.05$).

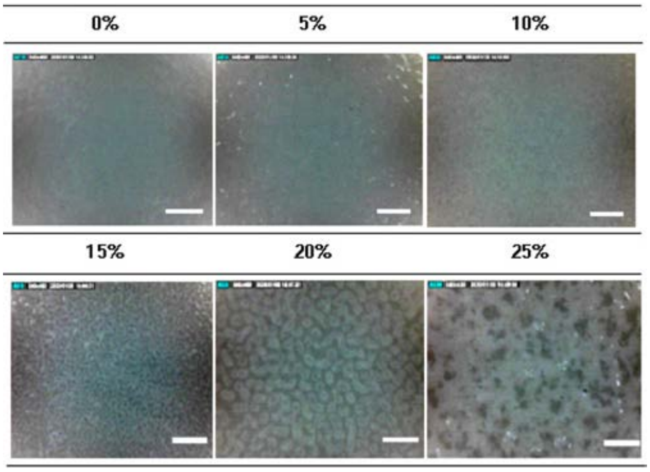

Figure 2. Surface morphological study and dispersion state of TiO_2 using a digital microscope (TiO_2 = 0, 5, 10, 15, 20, 25%, ×250, scale bar: 400 μm).

face hardness test of the TiO_2/PLCL composites at 20% and 25%. Meanwhile, composites with a TiO_2 concentration of less than 20% had a relatively high hardness of 5 B. The hardness of 5 B is sufficient for removing the coated tooth manicure by brushing teeth. Therefore, we suppose that the lower mechanical properties at 20% and 25% were because of the weakened interconnectivity and higher surface roughness due to excess TiO_2 particles in the composite. Enhanced whitening effect and good mechanical properties were observed with increasing TiO_2 concentration at a TiO_2 concentration of less than 20%. However, there was no clearly observed difference in the whitening effect in the composite at 10% and 15%. Therefore, a TiO_2 concentration of 10% was considered optimal because it resulted in good mechanical properties and an enhanced whitening effect.

Measurement of Dispersion State of TiO_2 Particles. The dispersion state of TiO_2 particles and the surface morphology of the films were studied using a digital microscope. As shown in Figure 2, the dispersion states of TiO_2 particles on the TiO_2/PLCL composites at 0, 5, and 10% were similar in a homogeneous state. Meanwhile, composites with more than 10% concentration showed an increase in clumps and surface roughness because of the lower dispersion efficiency of the white TiO_2 particles as pigments. The increased clumps and surface roughness were because of the higher surface area of TiO_2 particles.

Cytotoxicity of TiO_2/PLCL Composite Films. For cell toxicity evaluation, NIH3T3 cells were cultured on TiO_2/PLCL (50:50) composite films at TiO_2 concentrations of 0, 5, 10, 15, 20, and 25%. The initial cell adhesion and proliferation were affected by the TiO_2 concentration, except in case of the PLCL film prepared without TiO_2. However, low cell adhesion and proliferation were observed in the pure PLCL film prepared without TiO_2 (Figure 3). The cell initial adhesion efficiency is affected by the hydrophobic ratio on the surface. The contact angles of the TiO_2/PLCL (50:50) composite films with TiO_2 concentrations of 0, 5, 10, 15, 20, and 25% were 68, 63, 62, 62, 61, and 61°, respectively. However, the overall TiO_2/PLCL

Table 2. Properties of Poly(*L*-lactide-*co*-*ε*-caprolactone) (PLCL 50:50) according to TiO_2 Concentration (n=5, $^*P<0.05$)

TiO_2 (%)		0	5	10	15	20	25
Elastic recovery at 200% strain		94±2*	95±1*	95±2*	92±1*	88±2*	86±1*
Elongation at break (%)		1020±3*	1015±5*	1030±4*	1005±2*	980±5*	965±3*
Pencile hardness test		≤5B	≤5B	≤5B	≤5B	≤4B	≤4B
Lab	*L*	87.05	93.44	94.13	95.93	95.18	95.06
	a	0.49	-0.51	-0.54	-1.92	-2.01	-1.40
	b	8.61	3.32	2.54	1.33	0.69	-0.51

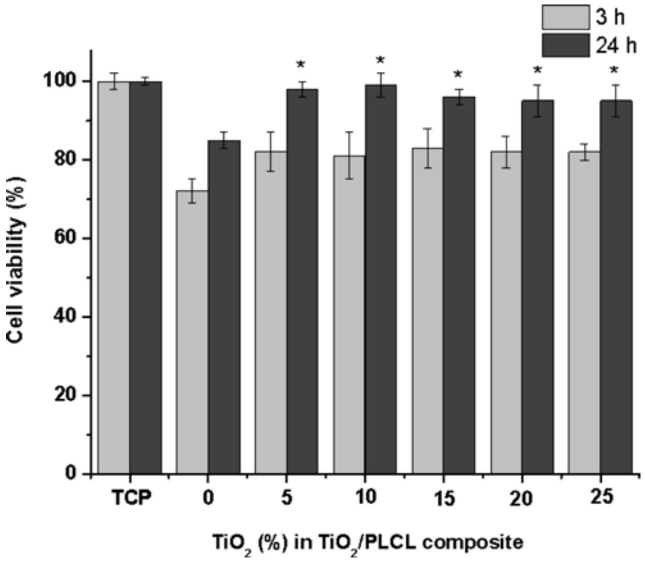

Figure 3. Cell viability of TiO_2/PLCL (50:50) according to TiO_2 concentration (n=5, *P>0.05).

composites appeared to be more hydrophilic than pure PLCL. Furthermore, no significant difference was observed between the films at TiO_2 concentration of 5, 10, 15, 20, and 25% and tissue culture plate after culturing for 24 h. Therefore, there was no toxicity.

Applies to Actual Tooth. Figure 4 shows photographs of the TiO_2/PLCL (50:50) composite at various TiO_2 concentrations applied to the teeth. As seen in Figure 4(a), pure PLCL applied to the tooth surface exhibited a colorless transparent coating film on yellow teeth. In contrast, Figure 4(b)-(f) show an increased whitening effect with increasing TiO_2 content. However, in the case of the PLCL composite with >15% TiO_2 concentration, an unnaturally painted strong white tooth was observed [(Figure 4(d)-(f))]. In contrast, uniform and natural coloring was observed in PLCL composites at 5% and 10%. This may have been because proper pigment content and good dispersion degree were used. Therefore, a PLCL composite with a TiO_2 concentration of 10% was considered optimal for dental manicure applications.

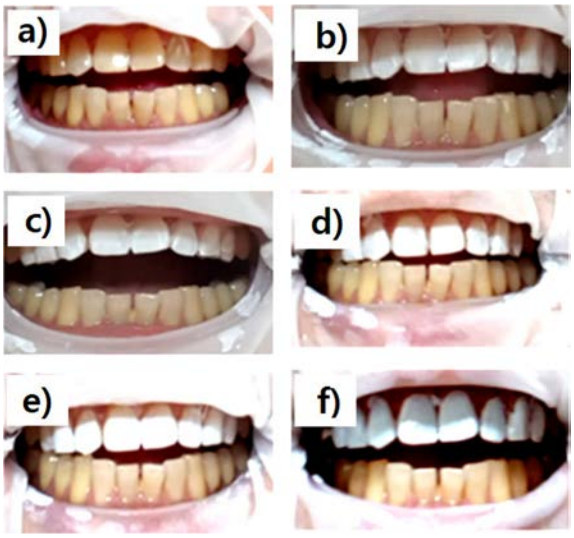

Figure 4. Photographs of the TiO_2/PLCL (50:50) composite at various TiO_2 concentrations applied to the teeth. (a) 0%; (b) 5%; (c) 10%; (d) 15%; (e) 20%; (f) 25%.

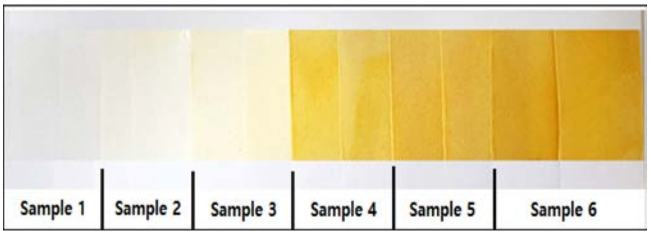

Figure 5. Various colors producing using gardenia yellow (sample number in Table 3).

Fabrication of Yellow-colored Composites. As the amount of gardenia yellow increased, the yellow color became stronger and clearer (Figure 5). From the quantitative analysis of colors, the colorimeter showed that the L value, as a white indicator, decreased while the b value, as a yellow indicator,

Table 3. Composition for Various Colors Producing Using Gardenia Yellow and Analysis of Colors

Samples	PLCL	TiO_2 (%)	Gardenia yellow	L	a	b
1	10% PLCL in ethyl acetate	15	0	95.92	-1.07	1.29
2		10	0	93.70	-0.62	2.36
3		0	0.2	88.49	-3.20	14.84
4		0	0.5	77.17	-0.21	41.18
5		0	1	77.35	1.62	52.58
6		0	3	74.64	3.44	65.84

increased with increasing gardenia yellow (Table 3).

The study also confirmed that it could be applied as a tooth manicure and has a variety of colors and whitening coating.

Conclusions

Effective dental manicure material was prepared by a simple method using a biodegradable elastic poly(L-lactide-*co*-ε-caprolactone) (PLCL) copolymer and TiO_2 particles in ethyl acetate solution. The tensile strength, elastic recovery, analysis of color, and cytotoxicity of the composites were studied to determine the optimal composition for tooth manicure applications. We found via mechanical property tests that PLCL at a molar ratio of 50:50 was the most effective composition to increase the elastic recovery and adhesive properties of the tooth coating. The TiO_2/PLCL mixture with a TiO_2 weight of 10% exhibited the highest dispersion of pigments and mechanical properties. Meanwhile, cell viability was improved in TiO_2/PLCL composites compared with pure PLCL. Further studies on the biological evaluation and biodegradable properties are required; however, the TiO_2/PLCL composite shows promise for use in implantable materials, for tooth whitening, and as protecting agent in the field of dentistry.

Acknowledgements: This work was supported by the Commercialization Promotion Agency For R&D Outcomes (COMPA) grant funded by the Korea government (MSIT) (1711121239).

References

1. Yu, H.; Zhang, C.-Y.; Cheng, S.-L.; Cheng, H. Effects of Bleaching Agents on Dental Restorative Materials: A Review of the Literature and Recommendation to Dental Practitioners and Researchers. *J. Dent. Sci.* **2015**, 10, 345-351.
2. Kwon, S. R. Whitening the Single Discolored Tooth. *Dent. Clin. N. Am.* **2011**, 55, 229-239.
3. Gerlach, R. W.; Barker, M. L.; Karpinia, K.; Magnusson, I. Single Site Meta-analysis of 6% Hydrogen Peroxide Whitening Strip Effectiveness and Safety Over 2 Weeks. *J. Dent*. **2009**, 37, 360-365.
4. Farawati, F. A. L.; Hsu, S.-M.; O'Neill, E.; Neal, D.; Clark, A.; Josephine, E.-U. Effect of Carbamide Peroxide Bleaching on Enamel Characteristics and Susceptibility to Further Discoloration. *J. Prosthet. Dent.* **2019**, 121, 340-346.
5. Junyuan, Q.; LiZeng, W.; Licheng, T.; Ruizhi, L.; Yiwang, C. A bio-safety tooth-whitening composite gels with novel phthalimide peroxy caproic acid. *Compos. Commun*. **2019**, 13, 107-111.
6. Fatemeh, A.; Kiana, B.; Mohammad, M. I.; Amin, G.; Roya, S.-F. Effect of Bleaching with Carbamide Peroxide on Shear Bond Strength of Orthodontic Brackets: A Meta-analysis of *in Vitro* Studies. *Int. Orthod.* **2020**, 18, 214-224.
7. Mohan, N.; Westland, S.; Brunton, P.; Ellwood, R.; Pretty, I. A.; Luo, W. A Clinical Study to Evaluate the Efficacy of a Novel Tray Based Tooth Whitening System. *J. Dent.* **2008**, 36, 21-26.
8. Choi, J. W.; Yang, S. Y.; Kwon, J. S.; Lee, S. B. Study on Testing Methods for Efficacy of Tooth Manicure Products. *Dent. Mater.* **2019**, 35, E10-e11.
9. Hashimura, T.; Yamada, A.; Iwamoto, T.; Arakaki, M.; Saito, K.; Fukumoto, S. Application of a Tooth-surface Coating Material to Teeth with Discolored Crowns. *Pediatr. Dent. J.* **2013**, 23, 44-50.
10. Eric, J. T. Recent Coating Developments for Combination Devices in Orthopedic and Dental Applications: A Literature Review. *Adv. Drug Deliv. Rev.* **2017**, 112, 88-100.
11. Fabián, M.-G.; Mario, F. D. G. Bonding Effectiveness of Tooth-colored Materials to Resin Cement Provided by Self-etching Silane Primer after Short- and Long-term Storage. *J. Prosthet. Dent*. **2019**, 212, 713.e1-713.e8.
12. Pitacas, H. M. G.; Cavalheiro, A.; Coito, C.; Silva, A.; Eira, R.; Lopes, M. Effect of External Tooth Bleaching on the Surface of Resin Composites – An *In Vitro* Studyefeito Do Branqueamento Dentário Externo Na Superfície Das Resinas Compostas – Estudo *In Vitro*. *Revista Portuguesa de Estomatologia, Medicina Dentária e Cirurgia Maxilofacial.* **2015**, 56, 149-155.
13. Yue, S.; Wu, J.; Zhang, Q.; Zhang, K.; Weir, M. D.; Imazato, S.; Bai, Y.; Xu, H. H. K. Novel Dental Adhesive Resin with Crack Self-healing, Antimicrobial and Remineralization Properties. *J. Dent*. **2018**, 75, 48-57.
14. Krifka, S.; Spagnuolo, G.; Schmalz, G.; Schweikl, H. A Review of Adaptive Mechanisms in Cell Responses Towards Oxidative Stress Caused by Dental Resin Monomers. *Biomaterials* **2013**, 34, 4555-4563.
15. Ma, P. X. Biomimetic Materials for Tissue Engineering. *Adv. Drug Deliv. Rev.* **2008**, 60, 184-198.
16. Nur, R. E. P.; Xiuhui, W.; Ying, C.; Xiaomeng, L.; Naoki, K.; Guoping, C. Preparation of PLGA-collagen hybrid scaffolds with controlled pore structures for cartilage tissue engineering. *Prog. Nat. Sci.-Mater.* **2020**, 30, 642-650.
17. Frydrych, M.; Román, S.; MacNeil, S.; Chen, B. Biomimetic poly(glycerol sebacate)/poly(l-lactic acid) Blend Scaffolds for Adipose Tissue Engineering. *Acta Biomater.* **2015**, 18, 40-49.
18. Chung, S.; Ingle, N. P.; Montero, G. A.; Kim, S. H.; King, M. W. Bioresorbable Elastomeric Vascular Tissue Engineering Scaffolds via Melt Spinning and Electrospinning. *Acta Biomater*. **2010**, 6, 1958-1967.
19. Kijeńska, E.; Prabhakaran, M. P.; Swieszkowski, W.; Kurzydlowski, K. J.; Ramakrishna, S. Interaction of Schwann Cells with Laminin Encapsulated PLCL Core–shell Nanofibers for Nerve Tissue Engineering. *Eur. Polym. J.* **2014**, 50, 30-38.
20. Chen, Z.; Han, S.; Zhou, S.; Feng, H.; Liu, Y.; Jia, G. Review of Health Safety Aspects of Titanium Dioxide Nanoparticles in Food Application. *NanoImpact*. **2020**, 18, 100224.

21. Padmanabhan, N. T.; John, H. Titanium Dioxide Based Self-cleaning Smart Surfaces: A Short Review. *J. Environ. Chem. Eng*. **2020**, 8, 104211.
22. Fernández, J.; Meaurio, E.; Chaos, A.; Etxeberria, A.; Alonso-Varona, A.; Sarasua, J. R. Synthesis and Characterization of Poly (*L*-lactide/ε-caprolactone) Statistical Copolymers with Well Resolved Chain Microstructures. *Polymer* **2013**, 54, 2621-2631.
23. Lim, J. I.; Lim, K. J.; Lim, H. N.; Lee, Y. K. Bond Strength of Experimental Cyanoacrylate-modified Dental Glass Ionomer Cement. *J. Mater. Sci.* **2010**, 45, 5211-5217.
24. Wang, C.; Zeng, J.; Wang, S.; Yang, Z.; Huang, Q.; Chen, P.; Zhou, S.; Liu, X. Influence of Surface Treatments on the Shear Bond Strength of Orthodontic Brackets to Porcelain. *Appl. Surf. Sci*. **2008**, 255, 416-418.
25. Landegren, T.; Risling, M.; Persson, J. K. E.; Sonde´n, A. Cyanoacrylate in Nerve Repair: Transient Cytotoxic Effect. *Int. J. Oral Maxillofac*. **2010**, 39, 705-712.
26. SilvaNunes-Halldorson, V. D.; Steiner, R. L.; Smith, G. B. Residual Toxicity after Biodegradation: Interactions Among Benzene, Toluene, and Chloroform. *Ecotoxicol. Environ. Saf.* **2004**, 57, 162-167.
27. Kim, H. A Case of Acute Toxic Hepatitis after Suicidal Chloroform and Dichloromethane Ingestion. *Am. J. Emerg. Med*. **2008**, 26, 1073.e3-1073.e6.
28. Khan, M. A.; Ahmad, R.; Srivastava, A. N. Effect of Ethyl Acetate Aroma on Viability of Human Breast Cancer and Normal Kidney Epithelial Cells. *In Vitro Integr. Med. Res*. **2017**, 6, 47-59.
29. Dudic, V. B.; Lang, N. P.; Mombelli, A. Microbiological and Clinical Effects of an Antiseptic Dental Varnish after Mechanical Periodontal Therapy. *J. Clin. Periodontol*. **1999**, 26, 341-346.