applied sciences

Article

Effect of Rubber Cup Rotational Speeds during Tooth Polishing on Sound, Early Caries, and Cracked Tooth Surfaces

A-Young Chun [1] and Hee-Eun Kim [2,*]

[1] Department of Health Science, Graduate School of Gachon University, Incheon 21936, Republic of Korea; dkdud2854@gachon.ac.kr
[2] Department of Dental Hygiene, Gachon University College of Medical Science, Incheon 21936, Republic of Korea
* Correspondence: hekim@gachon.ac.kr; Tel.: +82-32-820-4375

Abstract: High-speed rubber cup polishing can exacerbate tooth surface damage, especially when preexisting conditions such as early caries or cracks exist. This study aimed to quantify the extent of damage to sound teeth based on rotating rubber cup speed and assess the damage in relation to the tooth surface condition. Using a rubber cup, 36 sound teeth were polished at 100, 3000, and 10,000 rpm, and 24 teeth with early carious lesions and 24 cracked teeth were polished at 3000 and 10,000 rpm. Polishing was performed using a rubber cup and prophylaxis paste, applying an on–off method (3.0 N force for 3 s). Damage depth was quantified using a surface profilometer and examined using scanning electron microscopy. Polishing at 10,000 rpm caused significantly more damage to sound teeth than polishing at lower speeds (depth increase: 71.45 ± 15.12 μm at 100 rpm; 61.91 ± 17.82 μm at 3000 rpm; $p < 0.001$). Teeth with early carious lesions or cracks demonstrated more damage after polishing than sound teeth ($p < 0.05$). Therefore, the rotational speed of the rubber cup has a critical impact on the extent of enamel damage. Higher speeds can increase the damage depth in both sound and damaged tooth surfaces.

Keywords: cracked tooth syndrome; dental caries; dental enamel; dental polishing; enamel microabrasion

Citation: Chun, A.-Y.; Kim, H.-E. Effect of Rubber Cup Rotational Speeds during Tooth Polishing on Sound, Early Caries, and Cracked Tooth Surfaces. *Appl. Sci.* **2024**, *14*, 3888. https://doi.org/10.3390/app14093888

Academic Editor: Vittorio Checchi

Received: 5 April 2024
Revised: 24 April 2024
Accepted: 29 April 2024
Published: 1 May 2024

1. Introduction

Oral biofilm is a complex symbiotic community of bacteria that accumulate on the tooth surface, forming a unique ecosystem [1,2]. However, the prolonged presence of this biofilm on the tooth surface disrupts the homeostasis of the internal bacteria, leading to bacterial imbalance and consequently inducing oral biofilm-related diseases, such as dental caries and periodontal diseases [3,4]. Therefore, managing oral biofilm is essential for maintaining and managing oral health [5–7].

Tartar remaining on the tooth surface after scaling can increase the deposition rate of oral biofilm [8]. Polishing using a rubber cup combined with a prophylactic angle fitted to a low-speed dental handpiece and prophylactic paste is utilized to disrupt and remove biofilm, eliminate external stains, smoothen the tooth surface, and provide polishing after scaling [9,10]. However, failure to precisely control the rotational speed and pressure of the rubber cup during polishing can lead to tooth damage [11,12]. High rotational speeds can cause various types of tooth damage, including tooth surface wear and pulp damage [10,13–15]. Currently, it is recommended to polish teeth with a low and controlled speed of 3000 to 5000 revolutions per minute (rpm) using a low pressure in the rubber cup polishing procedure [10]. In most dental clinical settings, air-driven low-speed handpieces are more commonly used than electronic low-speed handpieces [16]. Based on our clinical experience, it is challenging to perform polishing at a consistent speed when using these unit chairs, as dental professionals must adjust the polishing speed solely using the foot controller. Therefore, accurately assessing the extent of tooth surface damage according to the rotational speed of the rubber cup is crucial.

The contraindications for rubber cup polishing include newly erupted teeth, cementum, dentin, demineralized areas, and restored tooth surfaces [17,18]. However, demineralized areas and cracked teeth can be difficult to detect visually [19,20], often leading to oversight during rubber cup polishing. Early carious lesions are characterized by mineral loss beneath the tooth surface, leaving the outermost layer intact but weakened [21–23]. Additionally, cracked teeth contain fine fissures that penetrate the enamel or dentin [24,25]. Therefore, applying excessive pressure or high-speed during rubber cup polishing can cause irreversible damage to these areas. Scaling on tooth surfaces with early carious lesions or cracks can lead to significantly more severe damage than that on sound tooth surfaces [26]. Consequently, it is essential to accurately assess the condition of each tooth surface and ensure that polishing is conducted under standardized settings for each tooth during rubber cup polishing. Nevertheless, to the best of our knowledge, no study has clearly defined standards for rubber cup polishing procedures based on the condition of the tooth surface. Therefore, in this study, we aimed to assess the damage to sound tooth surfaces at various speeds of the rotating rubber cup and to compare the damage to tooth surfaces with early carious lesions and cracks at certain rotational speeds with the damage to sound tooth surfaces.

2. Materials and Methods

2.1. Ethical Approval and Sample Size Calculation

This study was conducted after obtaining approval from the Gachon University Institutional Review Board (1044396-201904-HR-062-02), in accordance with the principles of the Declaration of Helsinki. The participants received explanations of the research objectives and methods, and written informed consent was obtained from those who agreed to the collection of their teeth. Subsequently, the extracted teeth were collected. To calculate the sample size for a one-way analysis of variance (ANOVA), G* Power software version 3.1 (Heinrich-Heine-University Düsseldorf, Düsseldorf, Germany) was used. Based on the results of a previous study [26], the effect size (f) was calculated to be 0.55, the probability of alpha error was set at 0.05, and the power was 0.80, resulting in a requirement of 12 teeth per group for this study.

2.2. Preparation of the Enamel Specimens

Molars extracted because of periodontal diseases, impaction, and orthodontic treatments, along with extracted third molars, were collected. The collected teeth were carefully cleaned to remove calculus and soft tissue without damaging the surface, followed by thorough washing under running water. Once completely dry, the teeth were photographed using a Quantitative Light-induced Fluorescence Digital (QLF-D Biluminator™2+; Inspektor Research Systems BV, Amsterdam, The Netherlands) camera. During photography, the QLF-D camera lens was positioned vertically 10 cm away from the tooth. Under white light, the shooting conditions of the QLF-D camera were as follows: shutter speed, 1/160 s; aperture, 8.0; ISO, 1600; manual white balance. When shooting under the blue light (405 nm) of the QLF-D camera, the conditions were as follows: shutter speed, 1/45 s; aperture, 10.0; ISO, 1600; and daylight white balance. The captured images were analyzed using QA2 software version 1.23 (Inspektor Research System BV, Amsterdam, the Netherlands), and the teeth were categorized into sound, early caries, and cracked conditions (Figure 1). To prepare the tooth specimens, the cervical part of the tooth was cut using a low-speed handpiece and diamond disc bur (Figure 2a), after which the crown was embedded in resin (Ortho-Jet, Lang Dental Mfg. Co., Inc., Wheeling, IL, USA) (Figure 2b). To maintain a baseline for tooth polishing, nail varnish (Easy Gel Top Coat, The Face Shop, Seoul, Korea) was applied to one-third of the tooth surface (Figure 2c).

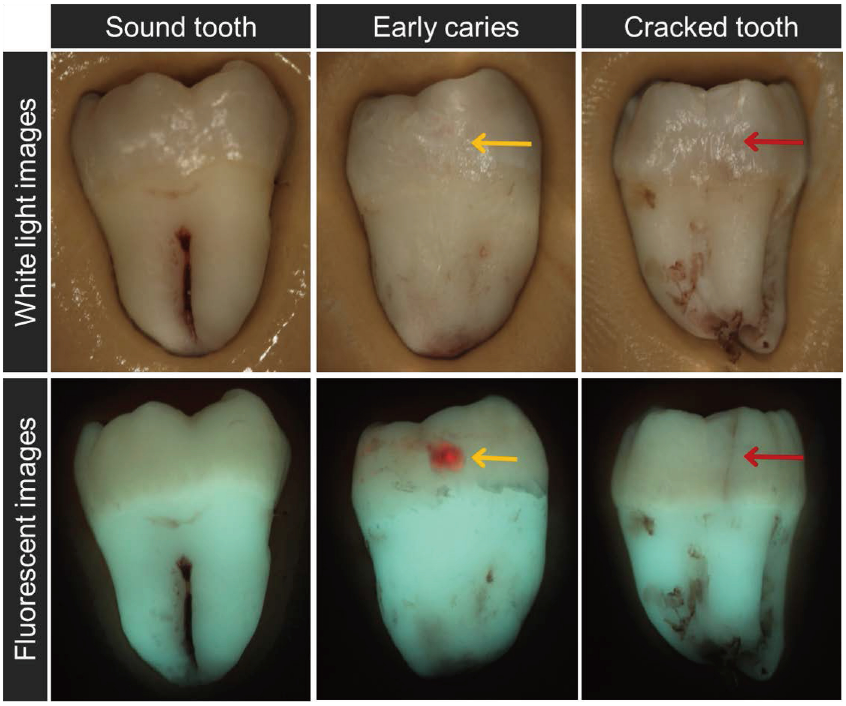

Figure 1. Various tooth defects captured using a quantitative light-induced fluorescence-digital camera. Yellow arrows: early carious lesions; red arrows: crack lines.

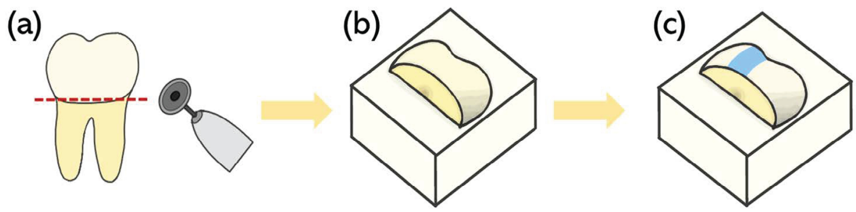

Figure 2. Process for the preparation of tooth specimens. (**a**) The cervical region of the tooth is sectioned using a diamond disc bur attached to a low-speed handpiece; (**b**) The sectioned crown is embedded in an acrylic resin; (**c**) Nail varnish was applied to the left third of the tooth surface. The blue area illustrates the nail varnish.

2.3. Rubber Cup Polishing

To guide our experimental design, we conducted a preliminary study to investigate the depths of defects on sound enamel at various rubber cup rotational speeds, ranging from 100 to 20,000 rpm. Our preliminary study findings revealed that rubber cup rotational speeds of 100, 3000, and 10,000 rpm showed the most significant differences in the preliminary results. Thus, these three speeds were used in the present study. To ensure the reliability of rubber cup polishing, a highly trained single dental hygienist was calibrated for the polishing procedure. The intraclass correlation coefficient was 0.924. To evaluate the damage to the tooth surface according to the rotating speed of the rubber cup, 36 sound teeth were selected and polished using a rubber cup at 3 different rotational speeds (100, 3000, and 10,000 rpm). Additionally, to assess the effect of rubber cup polishing based on tooth defects, 24 teeth with early carious lesions and 24 cracked teeth were obtained and subjected to rubber cup polishing at 3000 and 10,000 rpm. Polishing was performed on the specimens at 90° to the tooth surface using a rubber cup (Prophy Cup, ROCODENT, Foshan, GD, China) and prophylaxis paste (Nupro Prophy Paste, Nupro Polishing Paste Cups with fluoride mint/medium, Dentsply Sirona, Charlotte, NC, USA), using an on–off method with a force of 3.0 N for 3 s [17]. In particular, an electric motor (EM-E6 Tabletop Control Unit With EM-E6 Electric Motor, W&H Dentalwerk Bürmoos GmbH, Bürmoos, Austria) was used to consistently control the rotational speed of the rubber cup.

2.4. Measurement of Tooth Damage Depth

Before and after rubber cup polishing, the surface profile of each specimen was determined using a surface profilometer (Dektak XT Stylus Profiler, Bruker, Germany). Subsequently, the pre- and post-polishing profile values were graphically represented using Origin Pro 8.0 (OriginLab Co., Roundhouse Plaza, Northampton, MA, USA). To facilitate comparative analysis, the graphs before and after polishing were overlaid to produce a single composite graph. The initial profiling results were depicted as black curves, whereas the results following polishing were shown as red curves (Figure 3). On this combined graph, after three consistent points on the polished area were designated as index points (Figure 3), the depth of damage to the tooth surface was measured using Image-Pro version 11 (Media Cybernetics, Inc., Silver Spring, MD, USA) at these index points [26].

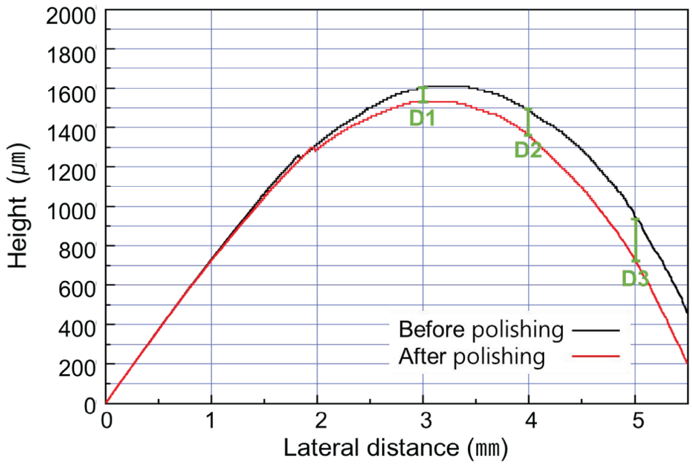

Figure 3. Overlay of pre- and post-polishing surface profiles obtained through surface profilometry. Black and red lines represent tooth surface profiles before and after polishing, respectively. D1–D3: depth of damage caused by rubber cup polishing on the tooth surface.

2.5. Observation of Damaged Tooth Surfaces

All specimens were coated with platinum for approximately 120 s at 20 mA using a platinum ion sputter (108 Auto Sputter Coater, Ted Pella, Redding, CA, USA) under vacuum. Subsequently, the tooth surfaces were observed at 50× magnification using a scanning electron microscope (JSM-7800F; JEOL, Ltd., Tokyo, Japan) with an acceleration voltage of 10–15 kV [27].

2.6. Statistical Analysis

All data were analyzed using IBM SPSS Statistics for Windows, version 28.0 (IBM Corp., Chicago, IL, USA), with the significance level set at 0.05. All data were subjected to normality testing using the Shapiro–Wilk test. Subsequently, one-way ANOVA and Tukey's post hoc analysis were conducted to compare the extent of damage to the tooth surface according to the rubber cup rotational speed under sound tooth surface conditions and to compare the extent of damage to the tooth surface according to the tooth condition at rubber cup rotational speeds of 3000 or 10,000 rpm.

3. Results

3.1. Damage Depth in Sound Teeth according to the Rotating Rubber Cup Speed

Rubber cup polishing at 10,000 rpm resulted in the most severe damage ($p < 0.001$) (Figure 4). Teeth polished at the rubber cup rotational speed of 10,000 rpm exhibited significantly deeper damage compared with those polished at 100 rpm (depth increase of 71.45 ± 15.12 μm, $p < 0.001$) and 3000 rpm (depth increase of 61.91 ± 17.82 μm, $p < 0.001$) (Figure 4).

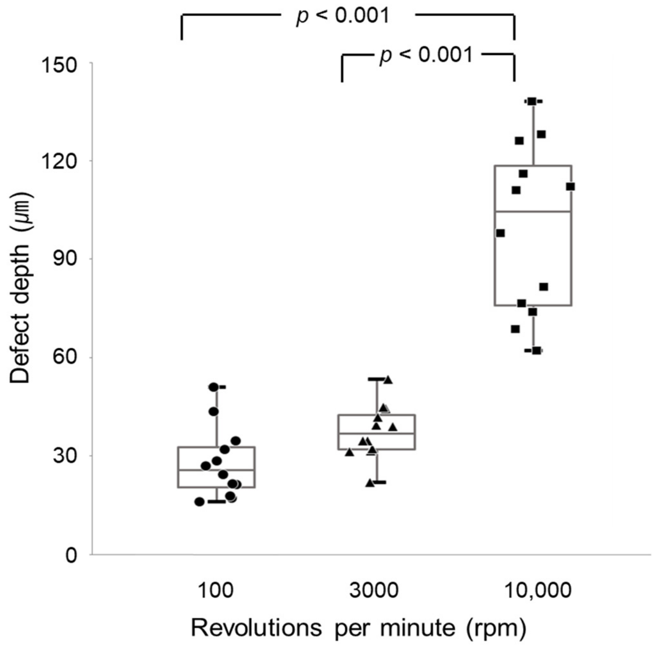

Figure 4. Depth of damage on sound teeth according to the rotating rubber cup speed.

3.2. Damage Depth according to Tooth Condition

Polishing at 3000 rpm caused 16.74 ± 11.99 μm and 28.01 ± 10.7 μm deeper damage to teeth with early carious lesions and cracked teeth, respectively, than to sound teeth ($p = 0.048$ and $p = 0.001$, respectively) (Figure 5). Polishing at 10,000 rpm caused 32.91 ± 6.00 μm deeper damage to teeth with early carious lesions than to sound teeth, although this difference was not statistically significant ($p = 0.076$). However, cracked teeth exhibited significantly deeper damage than sound teeth (59.60 ± 26.44 μm, $p = 0.001$) (Figure 6).

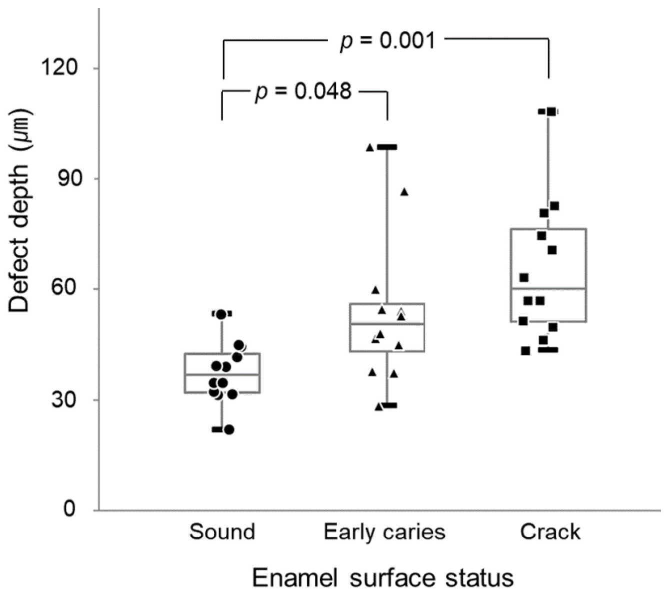

Figure 5. Tooth damage depth according to tooth condition when polishing with a rubber cup at 3000 rpm.

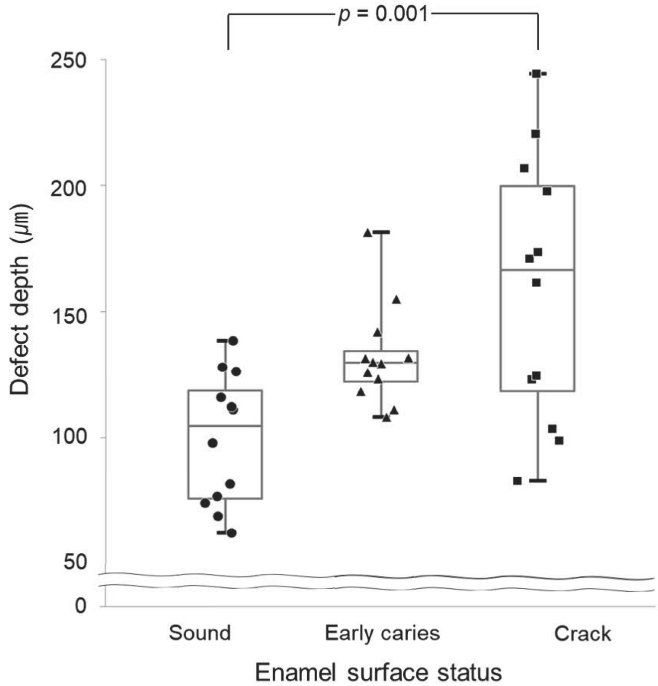

Figure 6. Tooth damage depth according to tooth condition when polishing with a rubber cup at 10,000 rpm.

3.3. Observation of the Tooth Surfaces after Rubber Cup Polishing

After polishing, teeth with early carious lesions or cracks exhibited more severe damage than those with sound surfaces (Figure 7). Surfaces with early carious lesions showed a distinct pattern in which the enamel rods were clearly exposed after polishing at 10,000 rpm (Figure 7). Furthermore, polishing surfaces with cracks at 3000 or 10,000 rpm resulted in clear patterns of deep destruction along the crack lines (Figure 7).

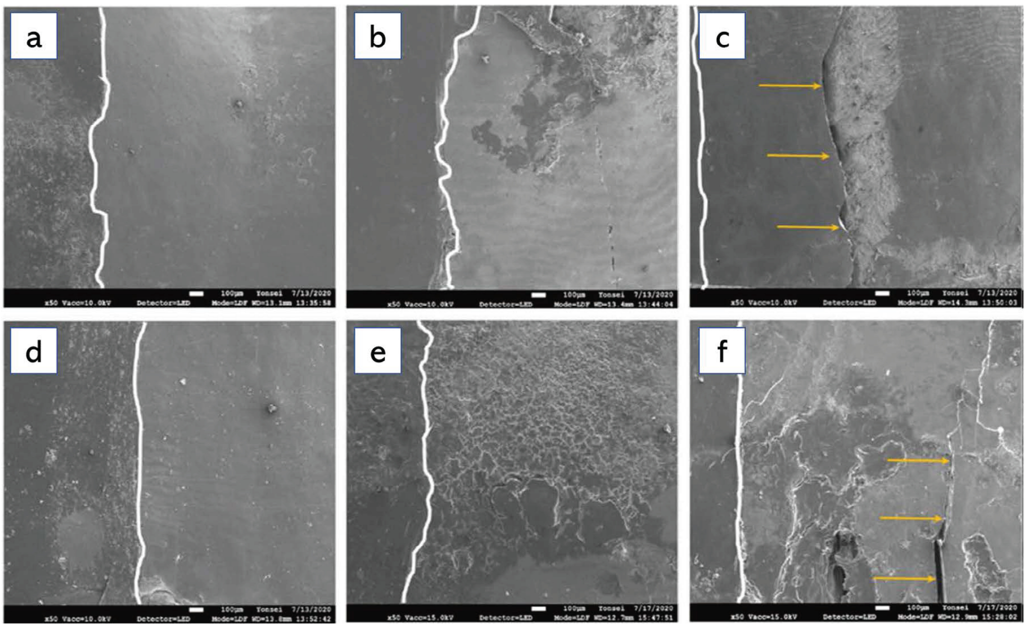

Figure 7. Scanning electron microscopy images of the tooth specimens (50×). (**a**) Sound enamel surface following rubber cup polishing at 3000 rpm. (**b**) Early carious lesion following rubber cup polishing at 3000 rpm. (**c**) Cracked enamel surface following rubber cup polishing at 3000 rpm.

(**d**) Sound enamel surface following rubber cup polishing at 10,000 rpm. (**e**) Early carious lesion following rubber cup polishing at 10,000 rpm. (**f**) Cracked enamel surface following rubber cup polishing at 10,000 rpm. The white line distinguishes the area where the rubber cup polishing was performed. The left side of the white line is protected with nail varnish, whereas the right side was exposed to polishing. The yellow arrows in (**c**,**f**) indicate the damage to the tooth surface along the crack lines after rubber cup polishing.

4. Discussion

During tooth polishing, the impact of various rubber cup rotational speeds on the depth of damage to the sound tooth surface was evaluated. Specifically, we compared the extent of damage to sound teeth, teeth with initial caries, and cracked teeth resulting from high-speed rotation of the rubber cup. Our study used three different rubber cup rotational speeds that hold particular clinical relevance. A speed of 100 rpm represented the lowest speed that can minimize damage to the tooth surface while achieving effective polishing. The 3000 rpm speed, recommended in dental hygiene practice books, served as a standard, guideline-based speed for comparison. Lastly, the 10,000 rpm speed, commonly used in clinical settings, represented the higher end of the spectrum, allowing for the evaluation of more aggressive polishing approaches. According to our findings, polishing sound teeth at 10,000 rpm resulted in significantly deeper damage (3.56 times and 2.65 times) compared with polishing at 100 rpm and 3000 rpm, respectively (Figure 4). While most previous studies recommended maintaining the lowest possible speed to minimize frictional heat [28,29], it is difficult to uniformly maintain the lowest speed in the dental clinical setting where the speed of the rotating rubber cup cannot be visually confirmed. Particularly, the speed considered the lowest by clinicians can vary significantly among individuals. Polishing at 10,000 rpm can wear away sound teeth up to a depth of about 100 μm, severely removing the outermost enamel layer (Figures 4 and 7), which contains the highest fluoride content [30]. Therefore, polishing can pose a significant risk of exposure to dental caries or erosion [31].

In addition, polishing at 3000 rpm reduced sound tooth surfaces by approximately 37.45 μm, with the depth of damage increasing by 1.45-fold and 1.75-fold in teeth with early caries or cracks, respectively, compared with that in sound teeth (Figure 5). Moreover, polishing at 10,000 rpm reduced sound tooth surfaces by 99.36 μm, with the depth of damage in cracked teeth increasing by 1.60-fold compared with that in sound teeth (Figure 6), with an average damage depth of >100 μm on surfaces with early caries and cracks. Scanning electron microscope observations revealed that the outer surfaces of the early carious teeth were worn such that the enamel rod pattern was visible (Figure 7). Early carious lesions are characterized by demineralization occurring beneath the surface of the tooth, leading to increased porosity and optical changes [32,33]. This indicates that the enamel at the surface remains intact, and demineralization occurs below the surface layer. Initial stages of carious lesions can undergo remineralization and halt lesion progression, restoring tooth structure, if they have not progressed to irreversible caries [33–35]. However, using excessively high speeds when polishing tooth surfaces with early carious lesions can lead to the loss of the outermost layer, resulting in the loss of enamel structure that could have been recovered through remineralization [36]. The loss of the outermost enamel layer that can be remineralized can accelerate the progression to a state of dental caries requiring restorative treatment [37]. Additionally, cracked teeth exhibited deep destruction patterns along the crack lines (Figure 7). Microcracks, which are incomplete fractures that extend into the dentin or pulp, can cause sharp pain during mastication and sensitivity to cold and sometimes hot foods [38–41]. Performing rubber cup polishing on cracked teeth can cause severe damage and accelerate the progression to a complete fracture. Thus, polishing at excessively high speeds on surfaces with hard-to-detect enamel damage, such as early carious lesions and cracks, can cause more significant damage than that on sound tooth surfaces.

The current clinical standards for rubber cup polishing are ambiguous, emphasizing low pressure and speed, and short, intermittent contact between the rubber cup and the tooth [10]. Without standard clinical guidelines, precisely controlling the pressure and speed of the rubber cup on the tooth surface is challenging and can potentially lead to excessive damage after polishing, as demonstrated in our study results. Moreover, teeth with high caries activity or existing cracks can experience accelerated enamel damage if polished without accurate assessment [42]. Therefore, dentists must thoroughly assess the condition of the tooth and accurately set the rotation speed of the rubber cup before proceeding with polishing to minimize damage. Additionally, developing patient-specific protocols that include the use of fluoride toothpaste, professional fluoride application, and other treatments to maximize the recovery of the tooth surface, along with adjusting the recovery interval of the tooth surface, is necessary [42,43].

While the findings of our study contribute significantly to the understanding of enamel damage due to various rubber cup rotational speeds, some limitations must be acknowledged. First, the extent of damage based on conditions applied during polishing, such as the rubber cup pressure, duration of use, and abrasive particle size, could not be assessed. Further studies are warranted to address these limitations and identify precise setting conditions for rubber cup polishing, because these factors are also critical in determining the extent of enamel damage. Understanding these factors will enable us to develop refined guidelines for dental practitioners, ensuring effective and safe polishing procedures. Second, the scope of our investigation was confined to the utilization of a single type of rubber cup in the rubber cup polishing procedures. Given the extensive array of rubber cups available in clinical practice, each with distinct physical properties, the generalizability of our findings could be constrained. Thus, it is imperative for further studies to explore the implications of using various types of rubber cups on polishing outcomes. Third, while enamel damage encompasses a range of conditions including early caries, cracks, cervical abrasion, and enamel hypoplasia, our study focused solely on early caries and cracks. Further studies should encompass a broader spectrum of enamel conditions to formulate comprehensive treatment guidelines that are applicable to diverse clinical scenarios. Fourth, our experimental design did not include interventions such as water spray that could mitigate the abrasion caused by rubber cup polishing. This decision was made to reflect the typical conditions present in clinical settings where rubber cup polishing is performed. Future studies should explore and assess methods to minimize the adverse effects of rubber cup polishing on tooth surfaces and enhance the safety and effectiveness of this common dental procedure. Fifth, our study relied on in vitro models, which, although providing controlled conditions, did not fully replicate the complex biological and mechanical interactions present in an in vivo setting. Particularly, our models did not consider the enamel's potential for recovery through remineralization by saliva. Studies that closely mimic the actual oral environment, utilizing designs that account for the remineralizing effects of saliva, are required to provide a more realistic assessment of enamel damage and recovery. Furthermore, the transition from in vitro to in vivo studies is a critical next step. Conducting longitudinal clinical trials will allow for the observation of the real-time effects of rubber cup rotational speeds on enamel, which is essential for translating findings directly into clinical practice. Finally, our study did not investigate the long-term effects of tooth polishing on the enamel's capacity for remineralization and the durability of the polished surfaces over time. Longitudinal studies should focus on these aspects to develop a deeper understanding of the implications of our findings for dental health and treatment protocols.

Despite these limitations, to the best of our knowledge, this study represents the first documented investigation into the effects of rubber cup polishing on tooth surfaces with early caries and microcracks, which are not visible to the naked eye. While previous studies focused predominantly on sound enamel, our study explores the nuanced impacts of polishing on compromised enamel—a critical area previously overlooked. By examining the response of these vulnerable surfaces to varying rubber cup rotational speeds, our findings challenge existing polishing protocols and underscore the necessity for customized approaches. This pioneering study underscores the importance of tailoring dental treatments to the specific conditions of the tooth surface, thereby significantly advancing our understanding of therapeutic interventions in dental practice.

5. Conclusions

The results of our study highlight the critical role of rubber cup rotational speed during polishing on the extent of enamel damage. The deepest damage occurred at a rotational speed of 10,000 rpm, with significantly deeper damage observed in teeth with early caries or cracks than in sound teeth. Our findings underscore the necessity for dental professionals to carefully assess the condition of each tooth and adjusting polishing speeds to minimize potential enamel damage, particularly in teeth with early carious lesions or cracks. Furthermore, our findings emphasize the need for further research under various experimental conditions to address diverse clinical scenarios. These findings suggest the need to develop patient-specific protocols and standardized clinical guidelines to ensure the safe and effective use of rubber cup polishing to protect the tooth surface and promote oral health.

Author Contributions: Conceptualization: H.-E.K.; methodology: A.-Y.C. and H.-E.K.; formal analysis: A.-Y.C. and H.-E.K.; writing—original draft preparation: A.-Y.C. and H.-E.K.; review and editing: H.-E.K.; funding acquisition: H.-E.K. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2022R1F1A1064357).

Institutional Review Board Statement: This study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board of Gachon University (protocol code: 1044396-201904-HR-062-02, approve date: 28 November 2019).

Informed Consent Statement: Written informed consent was obtained from all participants involved in the study.

Data Availability Statement: The data presented in this study are available from the corresponding author upon request.

Conflicts of Interest: The author declares no conflicts of interest.

References

1. Stoodley, P.; Sauer, K.; Davies, D.G.; Costerton, J.W. Biofilms as complex differentiated communities. *Annu. Rev. Microbiol.* **2002**, *56*, 187–209. [CrossRef] [PubMed]
2. Fulaz, S.; Vitale, S.; Quinn, L.; Casey, E. Nanoparticle-biofilm interactions: The role of the EPS matrix. *Trends Microbiol.* **2019**, *27*, 915–926. [CrossRef]
3. Takahashi, N.; Nyvad, B. The role of bacteria in the caries process: Ecological perspectives. *J. Dent. Res.* **2011**, *90*, 294–303. [CrossRef] [PubMed]
4. Nyvad, B.; Takahashi, N. Integrated hypothesis of dental caries and periodontal diseases. *J. Oral Microbiol.* **2020**, *12*, 1710953. [CrossRef] [PubMed]
5. Marsh, P.D.; Zaura, E. Dental biofilm: Ecological interactions in health and disease. *J. Clin. Periodontol.* **2017**, *44* (Suppl. S18), S12–S22. [CrossRef] [PubMed]
6. Jepsen, S.; Blanco, J.; Buchalla, W.; Carvalho, J.C.; Dietrich, T.; Dörfer, C.; Eaton, K.A.; Figuero, E.; Frencken, J.E.; Graziani, F.; et al. Prevention and control of dental caries and periodontal diseases at individual and population level: Consensus report of group 3 of joint efp/orca workshop on the boundaries between caries and periodontal diseases. *J. Clin. Periodontol.* **2017**, *44* (Suppl. S18), S85–S93. [CrossRef] [PubMed]
7. Axelsson, P.; Nyström, B.; Lindhe, J. The long-term effect of a plaque control program on tooth mortality, caries and periodontal disease in adults. Results after 30 years of maintenance. *J. Clin. Periodontol.* **2004**, *31*, 749–757. [CrossRef]
8. Cobb, C.M.; Sottosanti, J.S. A re-evaluation of scaling and root planing. *J. Periodontol.* **2021**, *92*, 1370–1378. [CrossRef]
9. Taylor, L. *Mosby's Dental Hygiene: Concepts, Cases and Competencies*, 2nd ed.; Mosby: London, UK, 2007; pp. 599–622.
10. Boyd, L.D.; Mallonee, L.F.; Wyche, C.J.; Halaris, J.F. *Wilkins' Clinical Practice of the Dental Hygienist*, 13th ed.; Jones & Bartlett Learning: Burlington, UT, USA, 2020; pp. 760–785.
11. Manly, R.S.; Foster, D.H. Importance of factorial designs in testing abrasion by dentifrices. *J. Dent. Res.* **1967**, *46*, 442–445. [CrossRef]

12. Sawai, M.A.; Bhardwaj, A.; Jafri, Z.; Sultan, N.; Daing, A. Tooth polishing: The current status. *J. Indian Soc. Periodontol.* **2015**, *19*, 375–380. [CrossRef]
13. Jefferies, R.W. Polishing dental enamel. *N. Z. Dent. J.* **1973**, *69*, 167–174. [PubMed]
14. Okumuş, Ö.F.; Orbak, R.; Özkan Karasu, Y.; Gül, P. The evaluation of different polishing techniques' effects on the post-operative external staining of enamel in primary and permanent tooth. *Cureus* **2023**, *15*, e39690. [CrossRef] [PubMed]
15. Naeem, A.; Basem, M.M.A.; Thamer, A.A.-G.; Mai, A.H.A.A.; Mahmoud, E. High-speed dental tools in dentistry-a review. *Int. J. Dent. Med. Spec.* **2018**, *5*, 18–21. [CrossRef]
16. Cho, H.J. Dental biofilm control of the disabled patients. *J. Korean Dent. Assoc.* **2018**, *56*, 432–436.
17. Pieren, J.A.; Bowen, D.M. *Darby and Walsh Dental Hygiene: Theory and Practice*, 5th ed.; Saunders: Maryland Heights, MI, USA, 2019; pp. 505–506.
18. Chowdhary, Z.; Mohan, R. Efficiency of three different polishing methods on enamel and cementum: A scanning electron microscope study. *J. Indian Soc. Periodontol.* **2018**, *22*, 18–24. [CrossRef] [PubMed]
19. Jun, M.K.; Park, S.W.; Lee, E.S.; Kim, B.R.; Kim, B.I. Diagnosis and management of cracked tooth by quantitative light-induced fluorescence technology. *Photodiagn. Photodyn. Ther.* **2019**, *26*, 324–326. [CrossRef] [PubMed]
20. Kim, H.E.; Kim, B.I. Early caries detection methods according to the depth of the lesion: An in vitro comparison. *Photodiagn. Photodyn. Ther.* **2018**, *23*, 176–180. [CrossRef] [PubMed]
21. Arends, J.; Christoffersen, J. The nature of early caries lesions in enamel. *J. Dent. Res.* **1986**, *65*, 2–11. [CrossRef]
22. Perdigão, J. Resin infiltration of enamel white spot lesions: An ultramorphological analysis. *J. Esthet. Restor. Dent.* **2020**, *32*, 317–324. [CrossRef]
23. Walsh, T.; Macey, R.; Ricketts, D.; Carrasco Labra, A.; Worthington, H.; Sutton, A.J.; Freeman, S.; Glenny, A.M.; Riley, P.; Clarkson, J.; et al. Enamel caries detection and diagnosis: An analysis of systematic reviews. *J. Dent. Res.* **2022**, *101*, 261–269. [CrossRef]
24. Ellis, S.G. Incomplete tooth fracture–proposal for a new definition. *Br. Dent. J.* **2001**, *190*, 424–428. [CrossRef] [PubMed]
25. Yu, M.; Li, J.; Liu, S.; Xie, Z.; Liu, J.; Liu, Y. Diagnosis of cracked tooth: Clinical status and research progress. *Jpn. Dent. Sci. Rev.* **2022**, *58*, 357–364. [CrossRef] [PubMed]
26. Kim, S.Y.; Kang, M.K.; Kang, S.M.; Kim, H.E. Effects of ultrasonic instrumentation on enamel surfaces with various defects. *Int. J. Dent. Hyg.* **2018**, *16*, 219–224. [CrossRef] [PubMed]
27. Kim, H.E.; Kwon, H.G.; Kim, B.I. Comparison of resistance to demineralization between the iontophoresis and the conventional fluoride application. *J. Korean Acad. Oral Health* **2008**, *32*, 10–19.
28. Tungare, S.; Paranjpe, A.G. *Teeth Polishing*; StatPearls Publishing LLC.: Treasure Island, FL, USA, 2024.
29. Chandra, D.; Bagchi, S. Tooth polishing: An overview. *Int. J. Prev. Clin. Dent. Res.* **2018**, *5*, S77–S78.
30. West, N.X.; Joiner, A. Enamel mineral loss. *J. Dent.* **2014**, *42*, S2–S11. [CrossRef] [PubMed]
31. Graumann, S.J.; Sensat, M.L.; Stoltenberg, J.L. Air polishing: A review of current literature. *J. Dent. Hyg.* **2013**, *87*, 173–180. [PubMed]
32. Harris, N.O.; Garcia-Godoy, F. *Primary Preventive Dentistry*, 6th ed.; Pearson: Upper Saddle River, Hoboken, NJ, USA, 2004; pp. 391–396.
33. Grohe, B.; Mittler, S. Advanced non-fluoride approaches to dental enamel remineralization: The next level in enamel repair management. *Biomater. Biosyst.* **2021**, *4*, 100029. [CrossRef]
34. Featherstone, J.D. The science and practice of caries prevention. *J. Am. Dent. Assoc.* **2000**, *131*, 887–899. [CrossRef]
35. Featherstone, J.D. Dental caries: A dynamic disease process. *Aust. Dent. J.* **2008**, *53*, 286–291. [CrossRef]
36. Ionta, F.Q.; Mendonça, F.L.; de Oliveira, G.C.; de Alencar, C.R.; Honório, H.M.; Magalhães, A.C.; Rios, D. In vitro assessment of artificial saliva formulations on initial enamel erosion remineralization. *J. Dent.* **2014**, *42*, 175–179. [CrossRef] [PubMed]
37. Mohabatpour, F.; Chen, X.; Papagerakis, S.; Papagerakis, P. Novel trends, challenges and new perspectives for enamel repair and regeneration to treat dental defects. *Biomater. Sci.* **2022**, *10*, 3062–3087. [CrossRef] [PubMed]
38. Cameron, C.E. The cracked tooth syndrome: Additional findings. *J. Am. Dent. Assoc.* **1976**, *93*, 971–975. [CrossRef] [PubMed]
39. Kakka, A.; Gavriil, D.; Whitworth, J. Treatment of cracked teeth: A comprehensive narrative review. *Clin. Exp. Dent. Res.* **2022**, *8*, 1218–1248. [CrossRef]
40. Hasan, S.; Singh, K.; Salati, N. Cracked tooth syndrome: Overview of literature. *Int. J. Appl. Basic Med. Res.* **2015**, *5*, 164–168. [CrossRef] [PubMed]
41. Banerji, S.; Mehta, S.B.; Millar, B.J. Cracked tooth syndrome. Part 1: Aetiology and diagnosis. *Br. Dent. J.* **2010**, *208*, 459–463. [CrossRef] [PubMed]
42. Fu, J.H.; Wong, L.B.; Tong, H.J.; Sim, Y.F. Conventional versus comprehensive dental prophylaxis: Comparing the clinical outcomes between rubber cup and air polishing and the importance of plaque disclosure. *Quintessence Int.* **2021**, *52*, 264–274. [CrossRef]
43. Amaechi, B.T. Remineralization therapies for initial caries lesions. *Curr. Oral Health Rep.* **2015**, *2*, 95–101. [CrossRef]