data

MDPI

Data Descriptor

Clinical Trial Data on the Mechanical Removal of 14-Day-Old Dental Plaque Using Accelerated Micro-Droplets of Air and Water (Airfloss)

Yumi C. Del Rey *, Pernille D. Rikvold *, Karina K. Johnsen and Sebastian Schlafer

Department of Dentistry and Oral Health, Section for Oral Ecology and Caries Control, Aarhus University, 8000 Aarhus, Denmark

* Correspondence: yumi@dent.au.dk (Y.C.D.R.); ptr@dent.au.dk (P.D.R.)

Abstract: Novel strategies to combat dental biofilms aim at reducing biofilm stability with the ultimate goal of facilitating mechanical cleaning. To test the stability of dental biofilms, they need to be subjected to a defined mechanical stress. Here, we employed an oral care device (Airfloss) that emits microbursts of compressed air and water to apply a defined mechanical shear to 14-day-old dental plaque in 20 healthy participants with no signs of oral diseases (clinical trial no. NCT05082103). Exclusion criteria included pregnant or nursing women, users of oral prostheses, retainers or orthodontic appliances, and recent antimicrobial or anti-inflammatory therapy. Plaque accumulation, before and after treatment, was assessed using fluorescence images of disclosed dental plaque on the central incisor, first premolar, and first molar in the third quadrant (120 images). For each tooth, the pre- and post-treatment plaque percentage index (PPI) and Turesky modification of the Quigley-Hein plaque index (TM-QHPI) were recorded. The mean TM-QHPI significantly decreased after treatment (p = 0.03; one-sample sign test), but no significant difference between the mean pre- and post-treatment PPI was observed (p = 0.09; one-sample t-test). These data are of value for researchers that seek to apply a defined mechanical shear to remove and/or disrupt dental biofilms.

Dataset: The dataset is submitted as a supplement

Keywords: biofilm removal; dental plaque index; clinical trial; cleaning device; Airfloss

Citation: Del Rey, Y.C.; Rikvold, P.D.; Johnsen, K.K.; Schlafer, S. Clinical Trial Data on the Mechanical Removal of 14-Day-Old Dental Plaque Using Accelerated Micro-Droplets of Air and Water (Airfloss). *Data* **2023**, *8*, 70. https://doi.org/10.3390/data8040070

Academic Editor: Jamal Jokar Arsanjani

Received: 10 February 2023
Revised: 8 March 2023
Accepted: 25 March 2023
Published: 31 March 2023

1. Summary

Recently, non-biocidal therapeutic strategies for dental biofilm control have gained increasing attention. Instead of eradicating oral bacteria with antiseptics [1,2], these strategies seek to reduce plaque stability by disrupting specific components of the biofilm matrix [3], or else by targeting bacterial adhesion [4,5]. Thereby, biofilms become less resistant to mechanical shear and may be removed more easily by oral hygiene procedures. To test dental biofilm stability in a clinical setting, they need to be subjected to a defined mechanical stress, and the biofilm removal needs to be quantified.

The Airfloss is an oral care device that emits accelerated micro-droplets of compressed air and water, which have been claimed to remove and/or disrupt dental biofilms by shear stress [6–9]. Here, we employed the Airfloss in the context of a clinical trial (clinicaltrials.gov; #NCT05082103) to apply a defined mechanical stress to the de novo-formed smooth surface dental biofilm, and tested its efficacy for biofilm removal. Treatment with the Airfloss device was applied to all study participants as a secondary outcome of the study protocol. This dataset provides information on the effect of 3 sequential triple microbursts of air and water to remove 14-day-old dental biofilms in a subset of 20 participants who were not subjected to any biofilm preventive therapy. The mechanical removal of plaque

was assessed using a continuous (plaque percentage index, PPI) [10] and an ordinal plaque index (Turesky modification of Quigley-Hein plaque index, TM-QHPI) [11], both of which are widely used to quantify dental plaque in the research environment [12].

Researchers that aim to apply a standardized mechanical shear to remove and/or disrupt dental biofilms may use these data as a basis to define optimal treatment parameters and to assess the efficacy of similar devices. These data are also useful for researchers that investigate treatments that weaken/destabilize dental biofilms and seek to apply a defined mechanical shear to evaluate treatment effects.

2. Data Description

This dataset contains clinical trial data on the amount of 14-day-old dental plaque, before and after Airfloss treatment, for 20 healthy participants with no signs of oral diseases. Biofilm accumulation was assessed using fluorescence images of teeth disclosed with 5% erythrosine. The Airfloss treatment consisted of three sequential triple microbursts of air and water. A total of 3 teeth per participant (central incisor, first premolar, and first molar in the third quadrant) were assessed after 14 days of de novo plaque formation using two plaque indices: the plaque percentage index (PPI) and the Turesky-modified Quigley-Hein plaque index (TM-QHPI). For each tooth, four data points were collected: the PPI and the TM-QHPI before and after treatment with the Airfloss device (total of 120 images).

The complete dataset is available as a Microsoft Excel spreadsheet (.xlsx file) (Microsoft Corporation, Redmond, WA, USA) (Supplementary Spreadsheet S1). Basic demographic information for all 20 participants includes gender and age in years. The plaque accumulation data is presented as PPI and TM-QHPI values for each of the assessed teeth (tooth 31: inferior left central incisor; 34: inferior left first premolar; 36: inferior left first molar) and as an average of the three teeth (average PPI and average TM-QHPI), both before (pre-treatment) and after (post-treatment) treatment with the Airfloss.

The pre- and post-treatment PPI and TM-QHPI recorded for all teeth for each participant are presented in Tables 1 and 2. The analyzed data on the average difference between pre- and post-treatment PPI and TM-QHPI for all 20 participants (n = 3 teeth per participant) are shown in Figure 1.

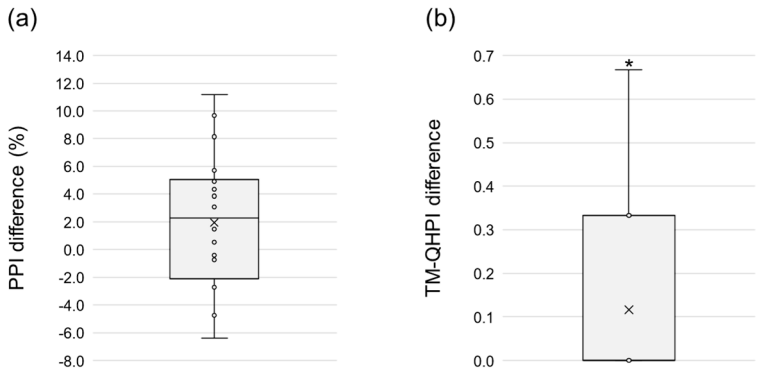

Figure 1. Differences between pre- and post-treatment values for the (**a**) planimetric plaque index (PPI) and the (**b**) Turesky modification of Quigley-Hein plaque index (TM-QHPI). No significant difference between the average PPI before and after treatment was observed (p = 0.09; one-sample t-test). The average TM-QHPI significantly decreased after treatment (* p = 0.03; one-sample sign test). Line and box = median and 25th/75th percentiles; "x" mark = mean; error bars = minimum and maximum.

Table 1. Planimetric plaque index (PPI) values before and after Airfloss treatment.

	Pre-Treatment			Post-Treatment		
	Tooth [1]					
Participant	**31**	**34**	**36**	**31**	**34**	**36**
1	7.27	19.87	46.37	4.74	17.03	47.29
2	47.25	66.20	86.27	50.54	59.80	87.74
3	40.76	46.20	73.15	41.51	48.36	78.40
4	15.54	23.13	32.82	14.97	20.64	24.32
5	59.92	44.32	80.15	63.50	42.69	80.46
6	16.52	10.66	8.38	30.46	12.97	11.25
7	13.22	19.87	38.65	4.24	9.09	24.87
8	21.57	58.21	60.83	14.84	40.02	61.33
9	35.17	43.36	46.33	41.97	44.50	52.63
10	8.74	18.17	43.25	6.91	17.68	33.96
11	25.05	12.80	24.65	17.44	15.53	16.46
12	20.74	36.51	73.36	16.27	36.05	62.94
13	28.44	20.52	47.61	27.79	31.65	50.62
14	41.27	34.81	41.48	40.25	28.94	31.26
15	24.32	26.97	51.11	15.59	29.63	47.97
16	62.51	51.60	63.83	41.84	55.56	51.49
17	20.85	19.26	36.26	20.56	20.98	37.09
18	15.01	32.56	69.73	16.87	31.31	76.77
19	5.84	13.30	36.91	10.11	12.96	34.20
20	29.18	18.65	79.23	17.05	16.79	78.43

[1] Dental notation = 31: inferior left central incisor; 34: inferior left first premolar; 36: inferior left first molar.

Table 2. Turesky modification of Quigley-Hein plaque index (TM-QHPI) scores before and after Airfloss treatment.

	Pre-Treatment			Post-Treatment		
	Tooth [1]					
Participant	**31**	**34**	**36**	**31**	**34**	**36**
1	3	3	4	2	3	4
2	3	5	4	3	4	4
3	4	4	5	4	3	5
4	3	3	4	3	3	4
5	4	4	5	4	4	5
6	3	3	3	3	3	3
7	2	3	3	1	3	3
8	3	4	4	2	4	4
9	3	3	4	3	3	4
10	3	3	4	3	3	4
11	3	3	3	3	3	3
12	3	3	4	3	3	4
13	3	3	4	3	3	4
14	4	3	3	4	3	3
15	3	3	5	3	3	5
16	4	5	4	4	5	4
17	3	3	5	3	3	5
18	3	3	5	3	3	5
19	2	3	4	2	3	4
20	3	3	5	2	2	5

[1] Dental notation = 31: inferior left central incisor; 34: inferior left first premolar; 36: inferior left first molar.

3. Methods

3.1. Study Participants

A total of 20 participants (mean age = 27.4 ± 9.77 years, 12 males, 8 females) were enrolled. The screening of the participants involved an anamnesis and a clinical examination. Individuals with at least 20 natural teeth, at least 18 years of age, and no signs of periodontal disease or active carious lesions were considered eligible for the study. A caries assessment was performed according to the Nyvad criteria [13], and only patients with no active (cavitated or non-cavitated) lesions were included. Periodontal disease was screened by measuring the clinical attachment level (CAL), pocket probing depth (PPD), and bleeding on probing (BOP). The study participants had no sites with PPD $\geq$ 3 mm or CAL $\geq$ 1 mm and BOP. Exclusion criteria included individuals with retainers, orthodontic appliances, intraoral piercings, or prostheses, as well as pregnant or nursing women. Individuals who had received antimicrobial or anti-inflammatory therapy within the past 30 days were also excluded.

3.2. Clinical Procedures

A professional tooth cleaning with dental scalers and a prophylaxis paste (Hawe Cleanic Fluoride KerrHawe SA, Bioggio, Switzerland) applied with a rubber cup (Hawe Pro-Cup, KerrHawe SA, Bioggio, Switzerland) in a slow-speed handpiece was performed on all participants, after which they were instructed to refrain from any oral hygiene measures for 14 days. After 14 days of de novo plaque formation, the central incisor, first premolar, and first molar in the third quadrant were disclosed by gently pressing a foam pellet containing 5% erythrosine (Top Dent Rondell Röd, Top Dent Lifco Dental AB, Enköping, Sweden) against the facial surface of the tooth. The participants were asked to rinse with 10 mL tap water for 10 s to remove the unbound dye, and then the teeth were air-dried for 3 s. The disclosed plaque on each tooth was imaged using an intraoral camera (VistaCam® Ix HD Smart; Dürr Dental, Bietigheim-Bissingen, Germany) in fluorescence mode. All images were acquired under dimmed room lights to avoid interference from external light, and the tooth surface was dried to prevent reflections or bubbles caused by the presence of saliva. The camera was positioned at 90°, and a standardized distance from the tooth surface (7 mm) was achieved using a custom-made black spacer, which also contributed to minimizing external light interference. All images were displayed using the plaque detection setting of the camera software (DBSWIN 5.17.0, Dürr Dental, Bietigheim-Bissingen, Germany) and exported as tif files [14].

Thereafter, an Airfloss device (Sonicare AirFloss Ultra; Royal Philips NV, Amsterdam, the Netherlands) was placed at 90° and 3 mm from the tooth surface by using a custom-made transparent adaptor. Three sequential triple microbursts of air and tap water were shot against the dental plaque on the facial aspect of each tooth. The teeth were then again disclosed with 5% erythrosine (Top Dent Rondell Röd), the participants rinsed with 10 mL tap water for 10 s, and the teeth were again air-dried for 3 s. A second set of fluorescence images was subsequently acquired, displayed, and exported as previously described. The intraoral fluorescence camera and the Airfloss device settings and specifications are presented in Tables 3 and 4, respectively.

The components, custom-made adaptors, and the assembly of the fluorescence camera and the Airfloss device can be seen in Figure 2. Both adaptors were 3D printed in resin (Ortho IBT, NextDent, Soesterberg, The Netherlands) and the respective STL files are available as supplementary material (Supplementary Files S1 and S2). Representative images of the 14-day-old disclosed dental plaque on the central incisor, first premolar, and first molar in the third quadrant, before and after treatment, are shown in Figure 3.

Table 3. Intraoral camera settings.

Trade name	VistaCam® iX HD Smart
Manufacturer	Dürr Dental
Camera head	Proof interchangeable head
Image type	Fluorescence images
Light source	Two LEDs [1]
Wavelength	380–460 nm (dominant: 405 nm)
Irradiance	0.5 W/m^2
Image resolution	1280 × 1024 pixels
Sensor	1/3″ CMOS [2]
ISO sensitivity	Automatic, by brightness control
Aperture	F13.6
Distance from tooth surface	7 mm (with custom-made adaptor)
Angulation in relation to tooth surface	90°

[1] LED: light-emitting diode; [2] CMOS: complementary metal-oxide-semiconductor.

Table 4. Airfloss device settings.

Trade name	Sonicare Airfloss Ultra
Manufacturer	Royal Philips NV
Burst mode	Three sequential triple bursts
Liquid	Tap water
Distance from tooth surface	3 mm (with custom-made adaptor)
Angulation in relation to tooth surface	90°

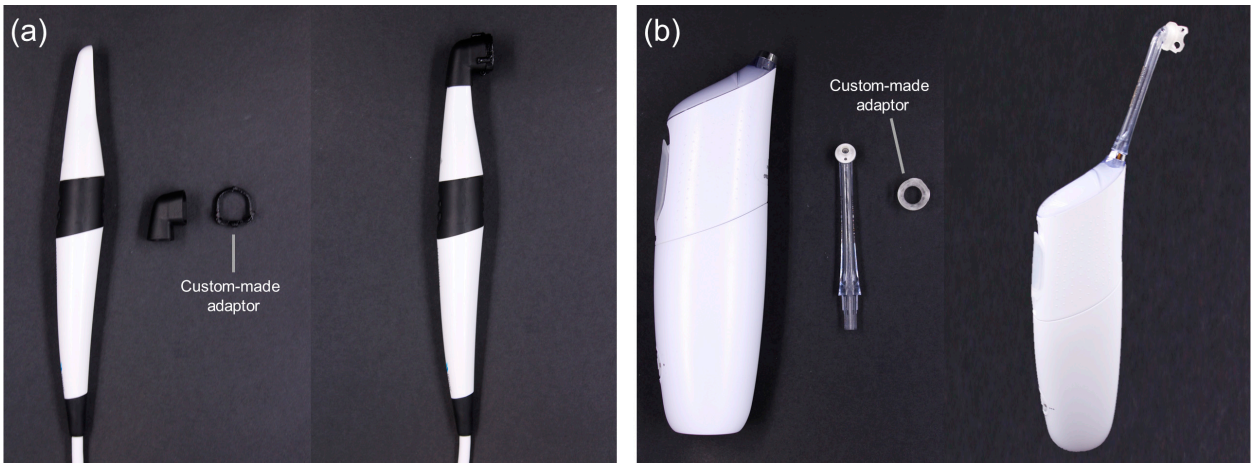

Figure 2. Components (left) and assembly (right) of the intraoral fluorescence camera (**a**) and the Airfloss device (**b**).

3.3. Dental Plaque Assessment

The plaque percentage index (PPI) and the Turesky modification of the Quigley-Hein plaque index (TM-QHPI) were recorded for all fluorescence images obtained before (n = 60) and after treatment (n = 60) with the Airfloss device.

The PPI measures plaque accumulation as the percentage of tooth area covered by disclosed plaque (continuous scale) and it was performed using a validated semi-automated quantification method [15] in a digital image analysis software (Daime; digital image analysis in microbial ecology, version 2.2.2) [16]. When irradiated with light in the blue spectrum, sound tooth surfaces exhibit green autofluorescence [17], whereas dental plaque disclosed with erythrosine emits red light. Using intensity thresholding, the total tooth area (green channel) and plaque-covered area (red channel) were identified as objects in each image, and background light derived from the surrounding tissues was removed. The percentage of tooth area covered by plaque was calculated by dividing the area in pixels of the plaque-covered area by the total tooth area and then multiplying the result by 100.

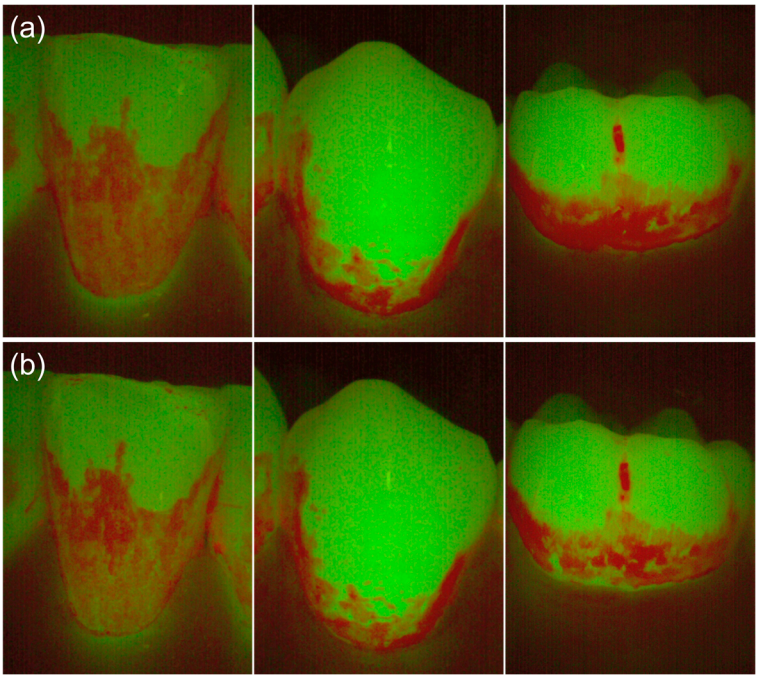

Figure 3. Disclosed dental plaque on an inferior left central incisor (tooth 31), an inferior left first premolar (tooth 34), and an inferior left first molar (tooth 36), before (**a**) and after (**b**) treatment with three sequential microbursts of air and water using the Airfloss device.

The TM-QHPI is a standard clinical plaque index that rates plaque accumulation in scores from 0 to 5 [11]. The TM-QHPI was scored by two independent assessors, and any disagreements were resolved by a third assessor. All assessors were previously trained and calibrated using a set of 25 fluorescence images of disclosed dental plaque. The scoring criteria of the TM-QHPI are presented in Table 5.

Table 5. Scoring criteria of the Turesky modification of the Quigley-Hein plaque index [11].

Score	Description
0	No visible plaque
1	Separate flecks of plaque at the cervical margin of the tooth
2	A thin, continuous band of plaque (up to 1 mm wide) at the cervical margin
3	A band of plaque wider than 1 mm but covering less than one-third of the crown
4	Plaque covering at least one-third but less than two-thirds of the crown
5	Plaque covering two-thirds or more of the crown

3.4. Data Analysis

The average difference between the pre- and post-treatment PPI and TM-QHPI for all 20 participants (n = 3 teeth per participant) was calculated. The data distribution was evaluated by the Shapiro-Wilk test and Levene's test. The one-sample t-test and one-sample sign test were used to compare differences between the pre- and post-treatment PPI and TM-QHPI, respectively. All statistical analyses were performed using the software R (www.r-project.org, accessed on 30 November 2022) with the significance level (α) set at 0.05.

4. User Notes

In clinical research, there is a need to apply a defined mechanical stress to dental plaque to test its stability and the effect of treatments that seek to destabilize dental plaque. This dataset illustrates the efficacy of three sequential triple microbursts of air and water using the Airfloss device to remove 14-day-old dental plaque in a clinical trial with healthy

participants. The mechanical removal of plaque was assessed using a continuous (PPI) and an ordinal plaque index (TM-QHPI), both of which are widely used in the research environment. The Airfloss treatment had no significant effect on the PPI, and a moderate but significant effect on the recorded TM-QHPI values. Our data can be used for comparative purposes to define optimal treatment parameters and to assess the efficacy of similar devices. It is important to note, however, that the study was performed in a subset of healthy participants, and care must be taken when extrapolating the results to different populations. All imaging and treatment specifications, including distance to the tooth surface and design files for the custom-made adaptors, are available in this data article and can be useful for researchers that seek to apply a standardized mechanical shear to test the stability of dental plaque.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/data8040070/s1, Spreadsheet S1: Basic demographic information and raw plaque accumulation data from 20 participants after 14 days of de novo dental plaque formation, before and after treatment with the Airfloss device. File S1: Custom-made spacer for the VistaCam fluorescence camera in STL format. File S2: Custom-made adaptor for the Airfloss device in STL format.

Author Contributions: Conceptualization, P.D.R. and S.S.; methodology, P.D.R. and S.S.; formal analysis, Y.C.D.R., K.K.J. and S.S.; investigation, Y.C.D.R., P.D.R. and K.K.J.; writing—original draft preparation, Y.C.D.R. and S.S.; writing—review and editing, Y.C.D.R., P.D.R., K.K.J. and S.S.; supervision, S.S. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Novozymes A/S and the Innovation Fund Denmark (grant number 9065-00244B).

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Ethical Committee of Region Midtjylland (1-10-72-259-21, approved on 1 September 2021).

Informed Consent Statement: Informed and written consent was obtained from all participants involved in the study.

Data Availability Statement: The data presented in this study are available in the article and as Supplementary Material.

Acknowledgments: Lene Grønkjær, Dirk Leonhardt, Javier E. Garcia, Charlotte K. Vindbjerg, and Sussi B. Eriksen are acknowledged for excellent technical assistance during the conduction of the study. Matthias Beck and Kim Sørensen are acknowledged for the technical support. Special gratitude to Mette R. Jørgensen for fruitful discussions.

Conflicts of Interest: The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

References

1. Bescos, R.; Ashworth, A.; Cutler, C.; Brookes, Z.L.; Belfield, L.; Rodiles, A.; Casas-Agustench, P.; Farnham, G.; Liddle, L.; Burleigh, M.; et al. Effects of Chlorhexidine mouthwash on the oral microbiome. *Sci. Rep.* **2020**, *10*, 5254. [CrossRef] [PubMed]
2. Al-Kamel, A.; Baraniya, D.; Al-Hajj, W.A.; Halboub, E.; Abdulrab, S.; Chen, T.; Al-Hebshi, N.N. Subgingival microbiome of experimental gingivitis: Shifts associated with the use of chlorhexidine and N-acetyl cysteine mouthwashes. *J. Oral Microbiol.* **2019**, *11*, 1608141. [CrossRef] [PubMed]
3. Pleszczyńska, M.; Wiater, A.; Bachanek, T.; Szczodrak, J. Enzymes in therapy of biofilm-related oral diseases. *Biotechnol. Appl. Biochem.* **2017**, *64*, 337–346. [CrossRef] [PubMed]
4. Kristensen, M.F.; Sørensen, E.S.; Del Rey, Y.C.; Schlafer, S. Prevention of Initial Bacterial Attachment by Osteopontin and Other Bioactive Milk Proteins. *Biomedicines* **2022**, *10*, 1922. [CrossRef] [PubMed]
5. Kristensen, M.F.; Zeng, G.; Neu, T.R.; Meyer, R.L.; Baelum, V.; Schlafer, S. Osteopontin adsorption to Gram-positive cells reduces adhesion forces and attachment to surfaces under flow. *J. Oral Microbiol.* **2017**, *9*, 1379826. [CrossRef] [PubMed]
6. Mazzoleni, S.; De Stefani, A.; Bordin, C.; Balasso, P.; Bruno, G.; Gracco, A. Dental water jet efficacy in the plaque control of orthodontic patients wearing fixed appliance: A randomized controlled trial. *J. Clin. Exp. Dent.* **2019**, *11*, e957–e963. [CrossRef] [PubMed]

7. Rmaile, A.; Carugo, D.; Capretto, L.; Aspiras, M.; De Jager, M.; Ward, M.; Stoodley, P. Removal of interproximal dental biofilms by high-velocity water microdrops. *J. Dent. Res.* **2014**, *93*, 68–73. [CrossRef] [PubMed]
8. Stauff, I.; Derman, S.; Barbe, A.G.; Hoefer, K.C.; Bizhang, M.; Zimmer, S.; Noack, M.J. Efficacy and acceptance of a high-velocity microdroplet device for interdental cleaning in gingivitis patients-A monitored, randomized controlled trial. *Int. J. Dent. Hyg.* **2018**, *16*, e31–e37. [CrossRef] [PubMed]
9. Rmaile, A.; Carugo, D.; Capretto, L.; Wharton, J.A.; Thurner, P.J.; Aspiras, M.; Ward, M.; De Jager, M.; Stoodley, P. An experimental and computational study of the hydrodynamics of high-velocity water microdrops for interproximal tooth cleaning. *J. Mech. Behav. Biomed. Mater.* **2015**, *46*, 148–157. [CrossRef] [PubMed]
10. Söder, P.-Ö.; Jin, L.J.; Söder, B. Computerized planimetric method for clinical plaque measurement. *Eur. J. Oral Sci.* **1993**, *101*, 21–25. [CrossRef] [PubMed]
11. Turesky, S.; Gilmore, N.D.; Glickman, I. Reduced plaque formation by the chloromethyl analogue of victamine C. *J. Periodontol.* **1970**, *41*, 41–43. [CrossRef] [PubMed]
12. Pretty, I.A.; Edgar, W.M.; Smith, P.W.; Higham, S.M. Quantification of dental plaque in the research environment. *J. Dent.* **2005**, *33*, 193–207. [CrossRef] [PubMed]
13. Nyvad, B.; Baelum, V. Nyvad Criteria for Caries Lesion Activity and Severity Assessment: A Validated Approach for Clinical Management and Research. *Caries Res.* **2018**, *52*, 397–405. [CrossRef] [PubMed]
14. Rikvold, P.D.; Del Rey, Y.C.; Johnsen, K.K.; Schlafer, S. Semi-Automated Planimetric Quantification of Dental Plaque Using an Intraoral Fluorescence Camera. *J. Vis. Exp.* **2023**, *191*, e65035. [CrossRef] [PubMed]
15. Del Rey, Y.C.; Rikvold, P.D.; Johnsen, K.K.; Schlafer, S. A fast and reliable method for semi-automated planimetric quantification of dental plaque in clinical trials. *J. Clin. Periodontol.* **2022**, *50*, 331–338. [CrossRef] [PubMed]
16. Daims, H.; Lücker, S.; Wagner, M. Daime, a novel image analysis program for microbial ecology and biofilm research. *Environ. Microbiol.* **2006**, *8*, 200–213. [CrossRef]
17. Amaechi, B.T.; Higham, S.M. Quantitative light-induced fluorescence: A potential tool for general dental assessment. *J. Biomed. Opt.* **2002**, *7*, 7–13. [CrossRef] [PubMed]