


BMJ Open Microbiological and clinical evaluation of ultrasonic debridement with/without erythritol air polishing during supportive periodontal therapy in arches with full-arch fixed implant-supported prostheses: protocol for a randomised controlled trial

Jingwen Yang,¹ Pingyi Jia ,² Zhaoguo Yue,³ Jianzhang Liu,¹ Zhongning Liu,¹ Lin Tang,¹ Qi Liu,⁴ Jianxia Hou³

To cite: Yang J, Jia P, Yue Z, *et al.* Microbiological and clinical evaluation of ultrasonic debridement with/without erythritol air polishing during supportive periodontal therapy in arches with full-arch fixed implant-supported prostheses: protocol for a randomised controlled trial. *BMJ Open* 2021;**11**:e053286. doi:10.1136/bmjopen-2021-053286

► Prepublication history for this paper is available online. To view these files, please visit the journal online (<http://dx.doi.org/10.1136/bmjopen-2021-053286>).

JY and PJ contributed equally. QL and JH contributed equally.

Received 09 May 2021

Accepted 07 November 2021



© Author(s) (or their employer(s)) 2021. Re-use permitted under CC BY-NC. No commercial re-use. See rights and permissions. Published by BMJ.

For numbered affiliations see end of article.

Correspondence to

Dr Qi Liu; dentistliuqi@sina.com

ABSTRACT

Introduction Implant-supported prostheses are often successfully used in edentulous patients. However, the incidences of peri-implant mucositis and peri-implantitis increase over time. The accumulation of pathogenic bacteria adjacent to prostheses can induce peri-implant disease. Plaque removal is recommended to prevent and manage peri-implant diseases. The purpose of this study is to compare the plaque removal efficacy of ultrasonic debridement with/without erythritol air-polishing powder around implants and bridges in patients with full-arch fixed implant-supported prostheses as well as the effects of these two methods on the rates of peri-implant mucositis and peri-implantitis, and the submucosal microbiota composition over 5 years in patients undergoing supportive periodontal therapy.

Methods and analysis We plan to enrol 10 edentulous (maxilla and/or mandible) patients seeking full-arch fixed implant-supported prostheses. The study will use a split-mouth model in which contralateral quadrants are randomly assigned to two groups. Group 1: one contralateral quadrant of full-arch fixed implant-supported prostheses will undergo ultrasonic debridement combined with erythritol air-polishing powder. Group 2: a separate contralateral quadrant of full-arch fixed implant-supported prostheses will undergo ultrasonic debridement. The 5-year trial will involve a total of 10 re-examinations per participant. The mucosal conditions around the implants will be recorded at 6-month intervals after restoration. Peri-implant submucosal plaque will be collected at each re-examination, and the bacterial flora will be analysed by 16s ribosomal RNA gene sequencing. X-ray examinations will be conducted at 12-month intervals to evaluate the marginal bone level around implants.

Ethics and dissemination This prospective single-centre, randomised controlled trial (PKUSSIRB-202054045) has been approved by the Ethics Committee of Stomatology School and Hospital of Peking University. Data will be registered with the International Clinical Trials Registry

Strengths and limitations of this study

- This is a randomised, prospective, separately controlled trial.
- The follow-up duration is 5 years.
- We will evaluate the effects of erythritol air-polishing alone; we will not evaluate the effects of other air-polishing materials.
- The influences of local conditions will not be excluded, such as the local keratinised mucosa width and the dental arch contour.
- The study will include only generally healthy patients; it will exclude patients with systemic diseases.

Platform. Additionally, we will disseminate the results via publication in scientific journals.

Trial registration number ChiCTR-2000032431.

INTRODUCTION

Implant-supported prostheses are often successfully used in edentulous patients.^{1 2} However, the incidences of peri-implant mucositis and peri-implantitis increase over time.³ In a long-term clinical study, 16%–29% of patients and 5%–6% of implants showed marginal bone loss indicative of peri-implantitis after 12–15 years of function.⁴ The accumulation of pathogenic bacteria adjacent to prostheses can induce peri-implant disease.^{5 6} Plaque removal is recommended to prevent and manage peri-implant diseases.⁷ Professional intervention is needed for plaque control around implant prostheses, particularly in patients with full-arch fixed implant-supported prostheses.⁸

Professional plaque cleaning may be performed using manual curettes,⁹ ultrasonic scalers,¹⁰ air polishers¹¹ and lasers.¹²

Air polishing uses abrasive powder in a stream of air to polish a microrough surface. It is an efficient mechanical debridement method for peri-implantitis treatment.¹³ Air polishing removes calculus and plaque,¹⁴ reduces peri-implant mucosal inflammation^{15–16} and has superior efficacy to manual curettes and ultrasonic scalers.^{10–17} However, few studies have investigated the influence of regular air polishing on peri-implant inflammatory diseases, or the influence of peri-implant bacteria removal on full-arch fixed implant-supported prostheses.¹⁸ The peri-implant microbiota are influenced by the flora of the remaining teeth in patients with partial edentulism¹⁹; our split-mouth randomised controlled trial will evaluate the effects of air polishing on the peri-implant microbiota.

This split-mouth randomised controlled trial is designed to compare the plaque removal efficacy of ultrasonic debridement with/without erythritol air-polishing powder around an implant and bridge in patients with full-arch fixed implant-supported prostheses as well as the effects of these two methods on the rates of peri-implant mucositis and peri-implantitis, and the submucosal microbiota composition over 5 years in patients undergoing supportive periodontal therapy.

METHODS AND ANALYSIS

Trial design

The proposed study is a 5-year randomised controlled trial. We plan to enrol 10 edentulous (maxilla and/

or mandible) patients seeking full-arch fixed implant-supported prostheses. The study will use a split-mouth model in which contralateral quadrants are randomly assigned to two groups. Group 1: one contralateral quadrant of full-arch fixed implant-supported prostheses will undergo ultrasonic debridement (ultrasonic devices with polyetheretherketone-coated tips, EMS Master 750) combined with erythritol air-polishing powder (EMS Air-Flow handy V.3.0, Perio). Group 2: a separate contralateral quadrant of full-arch fixed implant-supported prostheses will undergo ultrasonic debridement. The 5-year trial will involve a total of 10 re-examinations per participant. The mucosal conditions around the implants will be recorded at 6-month intervals after restoration. Peri-implant submucosal plaque will be collected at each re-examination, and the bacterial flora will be analysed by 16s ribosomal RNA (rRNA) gene sequencing. X-ray examinations will be conducted at 12-month intervals to evaluate the marginal bone level around implants (figures 1 and 2).

Study setting, ethical considerations and recruitment

This prospective randomised controlled trial (PKUSIRB-202054045) has been approved by the Ethics Committee of Stomatology School and Hospital of Peking University, China. In addition, the study is registered in clinicaltrials.gov (ChiCTR2000032431). Participants will be recruited at Stomatology School and Hospital of Peking University. We will approach participants who meet inclusion criteria about their interest regarding this study. If interested, potential participants will be referred to our study team members who will provide a detailed description of the study procedures and invite the individual to participate. Written, informed consent will be

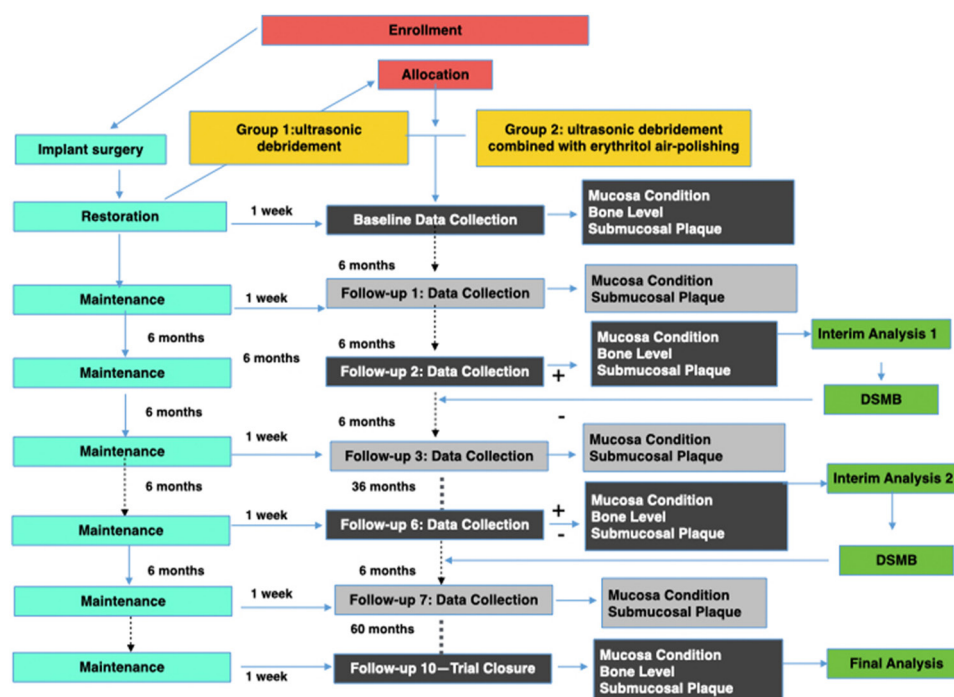


Figure 1 Consolidated Standards of Reporting Trials diagram.

TIMEPOINT	STUDY PERIOD												
	Enrolment			Allocation	Post-allocation								
	Prior to Allocation			Month0	Month6	Month12	Month18	Month24	Month30	Month36	Month42	Month48	Month54
ENROLMENT													
Implant surgery	X												
Eligibility screen	X												
Informed consent		X											
Restoration				X									
Allocation				X									
INTERVENTIONS													
Ultrasonic debridement combined with erythritol air-polishing powder				X									
Ultrasonic debridement				X									
ASSESSMENTS													
Implant survival rate						X				X			X
peri-implant plaque index				X	X	X	X	X	X	X	X	X	X
bleeding on probing				X	X	X	X	X	X	X	X	X	X
suppuration				X	X	X	X	X	X	X	X	X	X
probing depth				X	X	X	X	X	X	X	X	X	X
paralleling X-ray				X		X		X		X		X	
Microbiota sample collection				X	X	X	X	X	X	X	X	X	X

Figure 2 Participant timeline.

obtained prior to the collection of any study data. The clinical component of the study was initiated in May 2020 at the Stomatology School and Hospital of Peking University, China.

Patient and public involvement

Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research. Patients meet the inclusion criteria of this study will be involved in the recruitment. The patient will assess the burden of the intervention by themselves. The outcome measures will not be informed by patients' priorities, experiences and preferences. Data will be registered with the International Clinical Trials Registry Platform and will be disseminated to study participants.

Eligibility

Inclusion criteria are as follows: edentulous jaw, American Society of Anesthesiologists physical status I–II (generally healthy), good oral hygiene and good compliance and never smoker status. Exclusion criteria are age <18 years; antibiotic use in the past 3 months: if a participant uses an antibiotic in the last 3 months before recruitment, we will exclude him/her from this trial; systemic disease, including uncontrolled diabetes mellitus, cardiovascular disease, immune-related diseases, blood disorders (eg, coagulation disorders) and severe osteoporosis; long-term use of steroids, antiepileptics or bisphosphonates;

infection with HIV, hepatitis B or *Treponema pallidum*; bruxism, where sleep bruxism is rhythmic (phasic) or non-rhythmic (tonic) masticatory muscle activity during sleep, which is not a movement or sleep disorder in otherwise healthy individuals, while awake bruxism is repetitive or sustained tooth contact and/or bracing or thrusting of the mandible during wakefulness, which is not a movement disorder in otherwise healthy individuals^{20 21}; uncontrolled infection in the area intended for implant placement or other areas; maxillofacial tumour; face–neck radiotherapy; mental illness and/or inability to provide informed consent.

Interventions

The treatment plan comprises placement of four to eight implants in the maxilla and/or mandible. Participants will receive the following oral hygiene instructions before entering the study: brush your teeth two times per day using a manual or electric toothbrush and fluoride toothpaste for at least 5 min, use a Waterpik at least once per day, floss under the bridge as much as possible and do not use mouthwash.

The study will use a split-mouth model in which contralateral quadrants are randomly assigned to two groups. Group 1, one contralateral quadrant of a full-arch fixed implant-supported prostheses will undergo ultrasonic debridement (ultrasonic devices with

polyetheretherketone-coated tips, EMS Master 750) combined with erythritol air-polishing powder (EMS Air-Flow handy V.3.0, Perio) at 6-month intervals. Group 2, a separate contralateral quadrant of a full-arch fixed implant-supported prostheses will undergo ultrasonic debridement at 6-month intervals. One week after each follow-up, clinical and X-ray assessments will be performed. Subsequently, the prosthesis will be removed for microbiota sampling as well as ultrasonic debridement in group 1 and ultrasonic debridement combined with air polishing in group 2. After ultrasonic debridement and air polishing, irrigation with 0.12% chlorhexidine (ie, the most effective antiplaque mouthwash)²² will be performed for 1 min.

Outcome variables

The primary outcome variables will be the implant survival rate, peri-implant plaque index, peri-implant probing depth (PPD), peri-implant bleeding on probing (BOP), marginal bone loss and peri-implant submucosal bacteria. The secondary outcome variable will be peri-implant plaque staining.

Clinical assessment

Clinical examinations will be performed at baseline (immediately after prosthesis placement) and at 6-month intervals after final prosthesis placement. The following parameters will be evaluated during clinical examinations: peri-implant plaque index, BOP (0/1), suppuration (0/1) and PPD. The peri-implant plaque index, BOP, suppuration and PPD will be evaluated at six sites per implant: mesiobuccal, buccal, distobuccal, distolingual/palatal, lingual/palatal and mesiolingual/palatal.²³ PPD will be measured to the nearest millimetre using a graded probe (Hu-Friedy Manufacturing, Chicago, Illinois).

The peri-implant plaque index will be graded as follows: 0, no plaque in the gingival margin area; 1, thin plaque on the tooth surface of the gingival margin area not visible on scraping with the side of the probe tip; 2, medium amount of plaque on the adjacent surface; 3, large amount of soft dirt in the gingival sulcus or the gingival margin area and the adjacent surface.

Plaque staining will be performed as follows: a researcher will use tweezers to gently press a small cotton ball soaked with plaque stain (Sunstar, USA) on the bridge. Next, the patient will gargle two times. Digital images of the entire bridge area will be acquired after plaque staining using the standard imaging protocol.²⁴ Quantitative digital image analysis software (Image Pro Plus V.7.0) will be used to analyse the images. The Quigley-Hein plaque indices²⁵ of the bridge area will be evaluated by calculating the percent plaque-stained area.

To maximise reproducibility, the two examiners will be trained and calibrated prior to the trial.²⁶ The SE of continuous periodontal clinical parameters will be calculated. For the other clinical variables, >90% mean agreement between examiners will be considered satisfactory (Kappa test).

X-ray assessment

Marginal bone loss will be assessed as follows: periapical radiographs will be acquired immediately after final prosthesis placement, then annually thereafter. For standardisation, a paralleling technique will be used with an intramural digital system (Digora Toto, Soredex, Finland). Kodak Dental Imaging V.6.1 software (Carestream Health, Rochester, New York) will be used for radiographic analysis. The crestal bone level will be measured as the vertical distance from 2 mm below the implant–abutment interface to the most crestal part of the alveolar bone.^{27 28} In each group, the mean mesial and distal peri-implant marginal bone losses will be measured to the nearest millimetre using Scion Image software (Scion, Fredrick, Maryland).

Peri-implantitis lesions will be defined as PPD ≥ 5 mm, with either suppuration or the presence of BOP plus radiographic evidence of bone loss (>2 mm); alternatively, they will be identified by consensus among the clinicians involved in the study.²⁹ Peri-implant mucositis lesions will be defined as the presence of suppuration or the presence of BOP without radiographic evidence of bone loss. Clinically healthy implant sites will be defined as a probing depth ≤ 4 mm, absence of BOP or suppuration and no radiographic evidence of bone loss. The rates of peri-implantitis and peri-implant mucositis will be calculated at 1, 3 and 5 years after the final restoration.

Laboratory assessment

Sample collection

Sulcus sampling will be performed immediately before prosthetic treatment and at 6-month intervals after final prosthesis placement. Antimicrobial mouthwash will not be used within 48 hours of sampling, and food will not be consumed within 1 hour of sampling. Briefly, prior to sampling, clinical sites will be isolated and dried; supramucosal plaque and calculus will be carefully removed. Submucosal plaque around a single implant will be sampled by insertion of four sterile paper points (Number 30) into the base of the sulcus or pocket for 20 s. The paper points will be placed in labelled Eppendorf tubes and frozen for transportation to the laboratory.

Processing of microbiological samples

Detection of periodontopathic bacteria by PCR will use specific primers designed from 16s rRNA sequences. Genomic DNA will be isolated from collected samples using a TIANamp Micro DNA Kit (TianGen Biotech, Beijing, China). Detection of *Porphyromonas gingivalis*, *Fusobacterium nucleatum* spp and *Prevotella intermedia* will be performed by PCR in a thermal cycler (Gene Amp PCR System 2700, Foster City, California) using primers reported elsewhere.³⁰ PCR products will be electrophoresed in 2% agarose gels, stained with Goldview DNA Stain (TaKaRa Biotechnology, Dalian, PR China) and examined under 300 nm ultraviolet light (Bio-Rad, USA).

Sample size

Sample size was calculated by NCSS-PASS software. At 3 months, the PPD reduction induced by glycine powder air polishing combined with Teflon curettes debridement was reportedly 1.3mm (SD: 1.2mm). The reductions in *Treponema denticola*, *P. gingivalis* and *Tannerella forsythia* numbers were reportedly 2×10^5 , 5×10^5 and 2×10^5 , respectively. The PPD reduction by ultrasonic debridement was 0.91 mm (SD: 0.98mm).^{9 14} The reduction in BOP% at 3 months after erythritol powder air polishing was 40.45%,³¹ whereas it was 9% after ultrasonic debridement.³² The criteria for significance were $\alpha=0.05$ (type I error) and $\beta=0.10$ (type II error). The analysis was two tailed. Assuming a dropout rate of 30%, 18 implants per group and nine patients in total are needed.

Randomisation, allocation and blinding

The study will use a split-mouth model in which contralateral quadrants will be randomised by computer-generated permuted block randomisation with an allocation ratio of 1:1. Randomisation will be performed using sealed envelopes that will be opened after the final impression is recorded. Microbiota analysis will be performed in a blinded manner after assignment to interventions. Each sample will have a number associated with an allocation sequence, dental position and acquisition time. The PCR analyst will be blinded to sample identity.

Statistical methods

Statistical analysis will be conducted using Statistical Package for Social Sciences software (SPSS, V.19.0 for Macintosh, SPSS).

Clinical monitoring

Continuous variables will be described as means \pm SD or medians. Grade and quantitative data will be described as percentages. Age and other characteristics will be compared by independent t tests. Sex, implant survival rate, peri-implantitis rate and peri-implant mucositis will be compared by χ^2 tests. Clinical and X-ray indices will be compared by independent t tests. The mean percentages of sites with visible plaque, suppuration, PPD ≥ 5 mm and mean PPD will be computed for each participant and then averaged across participants in each group. Generalised estimating equations will be used to evaluate within-group and between-group differences. Actual p values will be reported; differences will be considered statistically significant when $p < 0.05$.

Microbiological monitoring

The mean counts ($\times 10^5$) of *P. gingivalis*, *F. nucleatum* spp and *P. intermedia* will be determined in each implant and each patient and then averaged across patients in the test and control groups. Between-group differences in microbiological parameters will be evaluated by the Wilcoxon signed rank test. Longitudinal differences in bacterial abundance will be analysed by the McNemar test. The level of statistical significance will be set at 5%.

Alpha and beta diversity analyses will be performed using Primer V.7 and QIIME V.2^{33 34}; these will include alpha diversity, Shannon's diversity index of species number and distribution, Margalef's index of numbers and Pielou's index of evenness of distribution.³⁵ The significance of differences between control and test participants will be assessed by unpaired Student's t tests. Beta diversity analysis will include visualisation of data at multiple taxonomic levels; unweighted and weighted UniFrac distance metrics will be used to generate principal coordinates analysis plots.³⁶ Analyses of similarity will be performed to determine whether microbial communities are significantly different between groups. Between-group differences in taxonomic abundance will be evaluated by White's non-parametric test, typically with a false discovery rate cut-off of 0.005, using STAMP software.³⁷

Interim analyses

Interim statistical analyses will be performed at 1 and 3 years after prosthesis placement. The analyst will be blinded to patient allocation and will submit the results to the Data and Safety Monitoring Board. The Data and Safety Monitoring Board will announce early termination of the study if the drop-out rate exceeds 20%.

Withdrawal

Patients will be informed at the beginning of study that they have the right to withdraw from the study at any time without providing a reason. Regardless of withdrawal, the required treatment will be provided to all patients. If a participant uses an antibiotic in the 3 months before a follow-up visit, we will collect submucosa samples, perform a clinical examination, record surface roughness and conduct an X-ray examination. We will discard the data from this follow-up. However, the participant will attend subsequent visits and undergo regular peri-odontal maintenance. If there is no antibiotic use within 3 months of the next follow-up, we will use the data from that follow-up.

DISCUSSION

Peri-implant diseases are common but lack a standard of care.^{38 39} Treatment and prevention of peri-implant lesions typically involve mechanical debridement of biofilm and calculus. Mechanical cleaning of full-arch fixed implant-supported prostheses comprises the use of oral hygiene devices and professional oral hygiene interventions. Full-arch fixed implant-supported prostheses are difficult to clean because of their structural complexity, particularly around implant neck surfaces. Furthermore, bridge units exhibit a tight fit with respect to underlying mucosa and gingiva. Removal of plaque from the mucosal surface is indispensable for oral hygiene. Typical oral hygiene devices (eg, manual brushes, dental floss and interdental brushes) do not reach the mucosal surfaces of these bridge units.⁴⁰ Bridge-optimised dental

floss, powered brushes⁴¹ and water flossers are recommended for this purpose. However, few patients with full-arch fixed implant-supported prostheses can maintain excellent oral hygiene in the absence of professional periodontal therapy.⁴¹ The proposed technique may enable submucosal biofilm removal around implants and bridges in patients with full-arch fixed implant-supported prostheses.

The major professional mechanical debridement methods are manual debridement, ultrasonic scaling with non-metal tips and air polishing. The instruments involved should be effective but not damage the prosthesis surface or disrupt the implant–soft tissue interface.⁴² Air polishing has been reported to significantly improve peri-implant mucosal health in peri-implant disease patients by reducing the plaque index and periodontal pathogen abundance.^{9, 17} This is the scientific basis of mechanical debridement and plaque control; it could prevent peri-implant inflammatory diseases. Furthermore, air-polishing powder has good biocompatibility⁴³ and causes few surface alterations.⁴⁴ However, air polishing has an unclear influence on the anti-inflammatory effects of ultrasonic scalers in patients with full-arch fixed implant-supported prostheses.

Glycine,⁴⁵ sodium carbonate⁹ and erythritol³¹ are the most frequently used air-polishing powders. Erythritol powder has a smaller particle size than glycine and sodium carbonate; it also exhibits low abrasiveness,³¹ a better taste, greater post-treatment biofilm regrowth inhibition⁴⁶ and greater water solubility.⁴⁷ Additionally, erythritol powder inhibits periodontopathogenic bacteria such as *P. gingivalis*.⁴⁸ Therefore, air polishing using erythritol powder has potential for use in supra-mucosal and submucosal biofilm management around dental implants without eliciting marked surface changes.

Individual differences influence treatment effectiveness⁴⁹; oral hygiene devices and plaque control affect the incidence and progression of peri-implant diseases.³⁷ This split-mouth randomised controlled study involving patients with full-arch fixed implant-supported prostheses will allow the comparison of plaque removal efficacy between ultrasonic debridement plus erythritol air-polishing powder versus ultrasonic debridement alone through the exclusion of other factors.

The limited evidence available precludes conclusions concerning the efficacy of air polishing for peri-implant diseases. Further studies of combined therapies for peri-implant diseases are needed.

Author affiliations

¹Department of Prosthodontics, Peking University School of Stomatology, Beijing, China

²Department of the Fourth Clinical Division, Peking University School of Stomatology, Beijing, China

³Department of Periodontology, Peking University School of Stomatology, Beijing, China

⁴Department of Implant dentistry, BYBO Dental Hospital Beijing, CN, Dongcheng District, Beijing, China

Acknowledgements We are grateful to the patients who participate. We appreciate the generous support from the Peking University School and Hospital of Stomatology. We thank the data collectors, supervisors, coordinators and the patient advisers for their significant contributions to the study.

Contributors JY, PJ, JL and ZY proposed the concept. QL and ZL designed the trial. JY and PJ drafted the manuscript. LT, JH and QL revised the sections concerning randomisation and calculation of sample size. LT and ZL reviewed and finalised the manuscript. All authors read and approved the final version of the manuscript.

Funding This study is supported by a research grant from the New Medical Technology Program of the Stomatological Hospital of Beijing University (PKUSSNT-19B11). The grant covers the ethics application and publication page fees.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Consent obtained directly from patient(s)

Provenance and peer review Not commissioned; externally peer reviewed.

Open access This is an open access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited, appropriate credit is given, any changes made indicated, and the use is non-commercial. See: <http://creativecommons.org/licenses/by-nc/4.0/>.

ORCID iD

Pingyi Jia <http://orcid.org/0000-0001-5772-4606>

REFERENCES

- Astrand P, Ahlqvist J, Gunne J. Implant treatment of patients with edentulous jaws: a 20-year follow-up. *Clin Implant Dent Relat Res* 2008;10:080411085817500.
- Kaneda K, Kondo Y, Masaki C, *et al*. Ten-year survival of immediate-loading implants in fully edentulous mandibles in the Japanese population: a multilevel analysis. *J Prosthodont Res* 2019;63:35–9.
- Windael S, Vervaeke S, Wijnen L, *et al*. Ten-year follow-up of dental implants used for immediate loading in the edentulous mandible: a prospective clinical study. *Clin Implant Dent Relat Res* 2018;20:515–21.
- Raval N, Dahlgren S, Teiwik A, *et al*. Long-term evaluation of ASTRA tech and brånemark implants in patients treated with full-arch bridges. Results after 12–15 years. *Clin Oral Implants Res* 2013;24:1144–51.
- Salvi GE, Ramseier CA. Efficacy of patient-administered mechanical and/or chemical plaque control protocols in the management of peri-implant mucositis. A systematic review. *J Clin Periodontol* 2015;42 Suppl 16:S187–201.
- Schwarz F, Sculean A, Engebretson SP, *et al*. Animal models for peri-implant mucositis and peri-implantitis. *Periodontol* 2000 2015;68:168–81.
- Schwarz F, Becker K, Bastendorf K-D, *et al*. Recommendations on the clinical application of air polishing for the management of peri-implant mucositis and peri-implantitis. *Quintessence Int* 2016;47:293–6.
- Corbella S, Del Fabbro M, Taschieri S, *et al*. Clinical evaluation of an implant maintenance protocol for the prevention of peri-implant diseases in patients treated with immediately loaded full-arch rehabilitations. *Int J Dent Hyg* 2011;9:216–22.
- Máximo MB, de Mendonça AC, Renata Santos V, *et al*. Short-term clinical and microbiological evaluations of peri-implant diseases before and after mechanical anti-infective therapies. *Clin Oral Implants Res* 2009;20:99–108.
- Schwarz F, Rothamel D, Sculean A, *et al*. Effects of an Er:YAG laser and the vector ultrasonic system on the biocompatibility of titanium implants in cultures of human osteoblast-like cells. *Clin Oral Implants Res* 2003;14:784–92.
- Sahm N, Becker J, Santel T, *et al*. Non-surgical treatment of peri-implantitis using an air-abrasive device or mechanical debridement and local application of chlorhexidine: a prospective, randomized, controlled clinical study. *J Clin Periodontol* 2011;38:872–8.
- Renvert S, Lindahl C, Roos Jansåker A-M, *et al*. Treatment of peri-implantitis using an Er:YAG laser or an air-abrasive device: a randomized clinical trial. *J Clin Periodontol* 2011;38:65–73.

- 13 Louropoulou A, Slot DE, Van der Weijden F. The effects of mechanical instruments on contaminated titanium dental implant surfaces: a systematic review. *Clin Oral Implants Res* 2014;25:1149–60.
- 14 Ji Y-J, Tang Z-H, Wang R, *et al.* Effect of glycine powder air-polishing as an adjunct in the treatment of peri-implant mucositis: a pilot clinical trial. *Clin Oral Implants Res* 2014;25:683–9.
- 15 Schwarz F, Becker K, Renvert S. Efficacy of air polishing for the non-surgical treatment of peri-implant diseases: a systematic review. *J Clin Periodontol* 2015;42:951–9.
- 16 Lupi SM, Granati M, Butera A, *et al.* Air-abrasive debridement with glycine powder versus manual debridement and chlorhexidine administration for the maintenance of peri-implant health status: a six-month randomized clinical trial. *Int J Dent Hyg* 2017;15:287–94.
- 17 Mussano F, Rovasio S, Schierano G, *et al.* The effect of glycine-powder airflow and hand instrumentation on peri-implant soft tissues: a split-mouth pilot study. *Int J Prosthodont* 2013;26:42–4.
- 18 Grusovin MG, Coulthard P, Worthington HV, *et al.* Maintaining and recovering soft tissue health around dental implants: a Cochrane systematic review of randomised controlled clinical trials. *Eur J Oral Implantol* 2008;1:11–22.
- 19 Tawil G, Barbeck M, Unger R, *et al.* Sinus floor elevation using the lateral approach and window repositioning and a xenogeneic bone substitute as a grafting material: a histologic, histomorphometric, and radiographic analysis. *Int J Oral Maxillofac Implants* 2018;33:1089–96.
- 20 Lobbezoo F, Ahlberg J, Raphael KG, *et al.* International consensus on the assessment of bruxism: report of a work in progress. *J Oral Rehabil* 2018;45:837–44.
- 21 Hokama H, Masaki C, Mukaibo T, *et al.* The effectiveness of an occlusal disclosure sheet to diagnose sleep bruxism: a pilot study. *Cranio* 2019;37:5–11.
- 22 Abdulkareem AA, Al Marah ZA, Abdulbaqi HR, *et al.* A randomized double-blind clinical trial to evaluate the efficacy of chlorhexidine, antioxidant, and hyaluronic acid mouthwashes in the management of biofilm-induced gingivitis. *Int J Dent Hyg* 2020;18:268–77.
- 23 Javed F, Al-Kheraif AA, Rahman I, *et al.* Comparison of clinical and radiographic periodontal status between habitual Water-Pipe smokers and cigarette smokers. *J Periodontol* 2016;87:142–7.
- 24 Maeda T, Mukaibo T, Masaki C, *et al.* Efficacy of electric-powered cleaning instruments in edentulous patients with implant-supported full-arch fixed prostheses: a crossover design. *Int J Implant Dent* 2019;5:7.
- 25 Turesky S, Gilmore ND, Glickman I. Reduced plaque formation by the chloromethyl analogue of vitamin C. *J Periodontol* 1970;41:41–3.
- 26 Araujo MWB, Benedek KM, Benedek JR, *et al.* Reproducibility of probing depth measurements using a Constant-Force electronic probe: analysis of inter- and intra-examiner variability. *J Periodontol* 2003;74:1736–40.
- 27 Abduljabbar T, Al-Sahaly F, Al-Kathami M, *et al.* Comparison of periodontal and peri-implant inflammatory parameters among patients with prediabetes, type 2 diabetes mellitus and non-diabetic controls. *Acta Odontol Scand* 2017;75:319–24.
- 28 Al Amri MD, Abduljabbar TS. Comparison of clinical and radiographic status of platform-switched implants placed in patients with and without type 2 diabetes mellitus: a 24-month follow-up longitudinal study. *Clin Oral Implants Res* 2017;28:226–30.
- 29 Heitz-Mayfield LJ, Aaboe M, Araujo M, *et al.* Group 4 ITI consensus report: risks and biologic complications associated with implant dentistry. *Clin Oral Implants Res* 2018;29 Suppl 16:351–8.
- 30 Ashimoto A, Chen C, Bakker I, *et al.* Polymerase chain reaction detection of 8 putative periodontal pathogens in subgingival plaque of gingivitis and advanced periodontitis lesions. *Oral Microbiol Immunol* 1996;11:266–73.
- 31 Hägi TT, Hofmänner P, Eick S, *et al.* The effects of erythritol air-polishing powder on microbiologic and clinical outcomes during supportive periodontal therapy: six-month results of a randomized controlled clinical trial. *Quintessence Int* 2015;46:31–41.
- 32 Karring ES, Stavropoulos A, Ellegaard B, *et al.* Treatment of peri-implantitis by the vector system. *Clin Oral Implants Res* 2005;16:288–93.
- 33 Caporaso JG, Kuczynski J, Stombaugh J, *et al.* QIIME allows analysis of high-throughput community sequencing data. *Nat Methods* 2010;7:335–6.
- 34 Hall M, Beiko RG. 16S rRNA gene analysis with QIIME2. *Methods Mol Biol* 2018;1849:113–29.
- 35 Shannon CE. The mathematical theory of communication. 1963. *MD Comput* 1997;14:306–17.
- 36 Lozupone C, Knight R. UniFrac: a new phylogenetic method for comparing microbial communities. *Appl Environ Microbiol* 2005;71:8228–35.
- 37 Parks DH, Tyson GW, Hugenholtz P, *et al.* Stamp: statistical analysis of taxonomic and functional profiles. *Bioinformatics* 2014;30:3123–4.
- 38 Figuero E, Graziani F, Sanz I, *et al.* Management of peri-implant mucositis and peri-implantitis. *Periodontol 2000* 2014;66:255–73.
- 39 Graziani F, Figuero E, Herrera D. Systematic review of quality of reporting, outcome measurements and methods to study efficacy of preventive and therapeutic approaches to peri-implant diseases. *J Clin Periodontol* 2012;39 Suppl 12:224–44.
- 40 Kanao M, Nakamoto T, Kajiwara N, *et al.* Comparison of plaque accumulation and soft-tissue blood flow with the use of full-arch implant-supported fixed prostheses with mucosal surfaces of different materials: a randomized clinical study. *Clin Oral Implants Res* 2013;24:1137–43.
- 41 Maeda T, Mukaibo T, Masaki C, *et al.* Efficacy of electric-powered cleaning instruments in edentulous patients with implant-supported full-arch fixed prostheses: a crossover design. *Int J Implant Dent* 2019;5:7.
- 42 Kuempel DR, Johnson GK, Zaharias RS, *et al.* The effects of scaling procedures on epithelial cell growth on titanium surfaces. *J Periodontol* 1995;66:228–34.
- 43 Louropoulou A, Slot DE, Van der Weijden F. Influence of mechanical instruments on the biocompatibility of titanium dental implants surfaces: a systematic review. *Clin Oral Implants Res* 2015;26:841–50.
- 44 Louropoulou A, Slot DE, Van der Weijden FA. Titanium surface alterations following the use of different mechanical instruments: a systematic review. *Clin Oral Implants Res* 2012;23:643–58.
- 45 Schwarz F, Ferrari D, Popovski K, *et al.* Influence of different air-abrasive powders on cell viability at biologically contaminated titanium dental implants surfaces. *J Biomed Mater Res B Appl Biomater* 2009;88:83–91.
- 46 Mensi M, Cochis A, Sordillo A, *et al.* Biofilm removal and bacterial re-colonization inhibition of a novel erythritol/chlorhexidine air-polishing powder on titanium disks. *Materials* 2018;11. doi:10.3390/ma11091510. [Epub ahead of print: 23 08 2018].
- 47 Munro IC, Berndt WO, Borzelleca JF, *et al.* Erythritol: an interpretive summary of biochemical, metabolic, toxicological and clinical data. *Food Chem Toxicol* 1998;36:1139–74.
- 48 Hashino E, Kuboniwa M, Alghamdi SA, *et al.* Erythritol alters microstructure and metabolomic profiles of biofilm composed of *Streptococcus gordonii* and *Porphyromonas gingivalis*. *Mol Oral Microbiol* 2013;28:435–51.
- 49 Schwarz F, Becker K, Sager M. Efficacy of professionally administered plaque removal with or without adjunctive measures for the treatment of peri-implant mucositis. A systematic review and meta-analysis. *J Clin Periodontol* 2015;42 Suppl 16:S202–13.