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ORIGINAL ARTICLE

Manual vs. interactive power toothbrush on plaque removal and salivary *Streptococcus mutans* and *Lactobacillus casei* levels

Single-center, examiner-blinded, randomized clinical trial in orthodontic patients

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Abstract

Introduction The purpose of this study was to compare efficacy of a manual and an interactive power toothbrush in orthodontic patients by assessing periodontal indexes and bacterial content of saliva samples.

Methods Forty patients (20 females, 20 males; age range 12–18 years) with fixed orthodontic appliances were included in the study. The patients were randomly divided into two groups in a 1:1 ratio using sealed envelopes: group 1: manual toothbrush (Oral-B Ortho Brush, Procter&Gamble Company, Dublin, Ireland), group 2: interactive power toothbrush (Oral-B Genius 8900, Procter&Gamble Company, Marktheidenfeld, Germany). All participants were given the same toothpaste (Colgate Triple Action, Colgate–Palmolive, New York, NY, USA). The brushing procedure for each patient was described in detail, both orally and visually, utilizing a video demonstration. Plaque and bleeding index scores were recorded for both the lower and upper arches at the beginning of the study (T0) and at weeks 6 (T1) and 12 (T2). In addition, the numbers of *Streptococcus* (*S.*) *mutans, Lactobacillus* (*L.*) *casei*, and *Porphyromonas* (*P.*) *gingivalis* bacteria were determined using a real-time polymerase chain reaction (PCR) analysis in saliva samples collected at T0, T1, and T2 times. Mann–Whitney U test and Student's t test were used to compare data between the groups, and one-way analysis of variance (ANOVA) and Friedman tests were used to compare data from different time intervals for each group.

Results Plaque index values were greater in group 1 at T1 and T2, although there was no difference between the groups at T0. The gingival index scores of both groups were similar at T0, T1, and T2. While group 2 had a larger number of salivary *S. mutans* at T0 and T2, there was no significant difference between the groups at T1. At all three time points, there was no significant difference in salivary *L. casei* levels between the groups.

Conclusions Although the interactive power toothbrush was more effective at removing plaque than the manual toothbrush, the results of the gingival index did not reflect the plaque scores. The number of certain salivary bacteria and brush type did not appear to have a clear relationship.

Keywords Oral hygiene · Plaque reduction · Gingivitis · Orthodontic patients · *Porphyromonas gingivalis*

Registration The trial was not registered.

Protocol The protocol was not published before trial commencement.

Availability of data and materials Data and materials are available at the Orthodontic Department in the Faculty of Dentistry, Afyonkarahisar Health Science University

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Manuelle vs. interaktive elektrische Zahnbürste zur Plaqueentfernung und Konzentration von *Streptococcus mutans* und *Lactobacillus casei* im Speichel

Unizentrische, randomisierte, prüferverblindete klinische Studie mit kieferorthopädischen Patienten

Zusammenfassung

Einleitung Ziel dieser Studie war es, die Wirksamkeit einer manuellen und einer interaktiven elektrischen Bürste bei kieferorthopädischen Patienten anhand von parodontalen Indizes und der Bakterienkonzentration in Speichelproben zu vergleichen.

Methoden Vierzig Patienten (20 weibliche, 20 männliche; Altersbereich 12-18 Jahre) mit festsitzenden kieferorthopädischen Apparaturen wurden in die Studie aufgenommen. Die Patienten wurden randomisiert mithilfe versiegelter Umschläge im Verhältnis 1:1 in 2 Gruppen aufgeteilt: Gruppe 1: Handzahnbürste (Oral-B Ortho Brush, Procter & Gamble, Dublin, Irland), Gruppe 2: interaktive elektrische Zahnbürste (Oral-B Genius 8900, Procter & Gamble, Marktheidenfeld, Deutschland). Alle Teilnehmer bekamen die gleiche Zahnpasta (Colgate Triple Action, Colgate-Palmolive, New York, NY, USA). Die Putztechnik für jeden Patienten wurde sowohl mündlich als auch visuell mit Hilfe einer Videodemonstration ausführlich dargestellt. Zu Beginn der Studie (T0), in Woche 6 (T1) und in Woche 12 (T2) wurden die Plaque- und Blutungsindexwerte für den unteren und oberen Zahnbogen erfasst. Darüber hinaus wurde die Anzahl der Bakterien *Streptococcus (S.) mutans, Lactobacillus (L.) casei* und *Porphyromonas (P.) gingivalis* mit Hilfe einer Real-Time-PCR(Polymerasekettenreaktion)-Analyse in Speichelproben bestimmt, die zu den Zeitpunkten T0, T1 und T2 gesammelt wurden. Für den Vergleich der Daten zwischen den Gruppen wurden der Mann-Whitney-U-Test und der Student-t-Test verwendet, für den Vergleich der Daten aus verschiedenen Zeitintervallen für jede Gruppe die Einwegvarianzanalyse (ANOVA) und der Friedman-Test.

Ergebnisse Die Plaqueindexwerte waren in Gruppe 1 bei T1 und T2 höher, obwohl es bei T0 keinen Unterschied zwischen den Gruppen gab. Die Gingivaindexwerte beider Gruppen waren bei T0, T1 und T2 ähnlich. Während Gruppe 2 zu T0 und T2 eine größere Anzahl von *S. mutans* im Speichel aufwies, gab es zu T1 keinen signifikanten Unterschied zwischen den Gruppen. Zu allen 3 Messzeitpunkten gab es keinen signifikanten Unterschied zwischen den Gruppen in Bezug auf die *L.-casei*-Konzentration im Speichel.

Schlussfolgerungen Die interaktive elektrische Zahnbürste entfernte Plaque effektiver als die Handzahnbürste. Die Ergebnisse des Gingivaindex spiegeln dagegen nicht die Plaquewerte wider. Die Konzentration bestimmter Bakterien im Speichel und die Art der Zahnbürste schienen in keinem eindeutigen Zusammenhang zu stehen.

Schlüsselwörter Mundhygiene · Plaquereduzierung · Gingivitis · Kieferorthopädische Patienten · *Porphyromonas gingivalis*

Introduction

One very important aspect of orthodontic therapy is maintaining good oral hygiene. Brackets, wires, and other equipment promote plaque formation and complicate traditional oral hygiene procedures [1–3]. Dental plaque levels are 2 to 3 times higher in patients undergoing fixed orthodontic treatment than in patients receiving no treatment [4]. Fixed orthodontic treatment not only promotes biofilm formation but also increases the amount of acidogenic bacteria in the biofilm [5]. Gingivitis is associated with the presence of biofilm, and the greater the plaque accumulation, the more severe the gingival bleeding and hyperplasia [6, 7]. As a result, an increase in dental plaque increases the risk of white spot lesions, caries, gingivitis, and periodontitis [8, 9].

The main cariogenic microorganism in dental plaque has been identified as *Streptococcus* (*S.*) *mutans* [10]. *Lactobacillus* species are thought to be secondary invaders of existing caries lesions, promoting caries progression [11]. It is known that the number of *S. mutans* can multiply up to 5 times during orthodontic treatment [12]. Similarly, the number of *Lactobacillus* species is increasing due to poor oral hygiene during orthodontic treatment [13]. *Lactobacillus* (*L.*) *fermentum, L. rhamnosus, L. gasseri, L. casei/paracasei, L. salivarius,* and *L. plantarum* are the dominant species in both adult and childhood caries [14]. Badet et al. reported that the *L. casei* group is the most common lactobacillus species in caries [15]. It has also been suggested that an increase in the saliva of some bacterial species, such as *Porphyromonas* (*P.*) *gingivalis*, is linked to periodontal disease [16, 17].

Saliva is sterile as it enters the oral cavity [18]. However, analysis of saliva from the oral cavity shows hundreds of millions of bacteria in one milliliter of saliva [19]. It has been discovered that the microbiological content of saliva is a collection of bacteria shed from the mouth's surfaces [20]. Therefore, saliva could potentially be used as a biomarker of oral health status [21].

The most effective way to maintain good oral hygiene during orthodontic treatment is to effectively remove dental plaque and prevent its accumulation [22]. Manual or power toothbrushes are the most basic tools used for this purpose. Power toothbrushes were first commercially introduced in the early 1960s as an alternative to the manual toothbrush [23]. However, there is no agreement in the literature on whether manual or power brushes are superior to one another. Some researchers suggest that electric toothbrushes are a potential alternative for plaque control in patients undergoing fixed orthodontic treatment [24], whereas others claim that there is no difference in plaque removal efficacy or gingival inflammation reduction between the two types of brushes [25].

Specific objectives and hypothesis

The aim of this study was to compare the effects of Bluetooth-enabled power brushes (Oral-B Genius 8900, Procter&Gamble Company, Marktheidenfeld, Germany) and manual orthodontic brushes (Oral-B Ortho Brush, Procter&Gamble Company, Dublin, Ireland) on oral hygiene in patients undergoing fixed orthodontic treatment, both clinically and microbiologically, using periodontal index measurements and real-time polymerase chain reaction (PCR) analysis.

The null hypothesis of this study was that using power or manual toothbrushes in patients with fixed orthodontic appliances made no difference in periodontal health or salivary microflora.

Materials and methods

Trial design and any changes after trial

The current study was a single-center, examiner-blinded, randomized clinical trial using a 1:1 allocation strategy. The methodology remained unaltered after the research started.

Participants, eligibility criteria, and settings

The experimental protocol of the current research was approved by the Clinical Research Ethics Committee of Afyonkarahisar Health Science University (ID:103/06.03.2020). Informed consent forms were obtained from all participants or their legal guardians. Inclusion criteria were using 0.018-inch slot Roth brackets and ligature wires, completion of the leveling and aligning phase, patients who are right-handed, between the ages of 12 and 18, and who brush their teeth with a manual toothbrush on a daily basis with no physical or mental disorders, mean plaque index score ≥ 1.75 according to the Turesky-modified Quigley–Hein plaque index. Exclusion criteria were systemic disease, regular drug use, rotations or a diastema in the arches, additional material such as chains, figure-eight ligatures, or coil springs, poor patient compliance, smoking, labial surface restorations of a tooth, presence of active antibiotic treatment or using antibacterial agents in the last 3 months, having antibiotics or antibacterial agents in follow-up appointments.

Sample size calculation

The sample size calculation using G*Power software revealed that at least 40 patients were required (effect size = 0.95, $\alpha = 0.05$, and $1 - \beta = 0.80$, actual power: 0.815) [26]. A total of 40 individuals (20 females, 20 males; age range 12–18) with fixed orthodontic appliances were included in the study.

Randomization

The patients were randomly divided into two groups in a 1:1 ratio using sealed envelopes: group 1: manual orthodontic toothbrush (MOTB), group 2: interactive power toothbrush (IPTB). Male and female patients were evenly distributed to the groups using stratified randomization.

Blinding

A single researcher was responsible for periodontal index scoring and saliva sample collection (T.E.). Because the current study was designed as an examiner-blinded, another clinician (M.Ş) was in charge of allocating patients to groups, delivering toothbrushes, and performing oral hygiene training. As a result, during data collection and statistical analysis stages, the researcher was blinded (T.E.). Furthermore, the researcher (M.E.) who evaluated the real-time PCR results was blinded, so he did not know which group the saliva samples belonged to.

Interventions

Each patient in group 1 was given a MOTB (Oral-B Ortho Brush). This manual orthodontic toothbrush has soft bristles that are positioned in a V-shape and are shorter in the center. Twenty IPTB (Oral-B Genius 8900), precision clean brush heads (EB20), and phone holders were distributed to patients in group 2. These power brushes remove plaque by employing rotation, oscillation, and vibration movements. The brush can perform 10,500 rotating–oscillating and 45,000 pulsating movements per minute. When too much pressure is applied to the teeth and gums with these brushes, the red warning light turns on and the brush slows down. They can connect with smart phones using Bluetooth

Table 1 Real-time polymerase chain reaction (PCR) primer sequences
Tab. 1 Primer-Sequenzen für die Real-time-Polymerasekettenreaktion (PCR)

Bacteria	Sequence	Base length (bp)	T_m (°C)	Reference
Streptococcus mutans				
Forward	GCCTTTACGGTGTGGTCCATCAA	123	58	NZ_CP044221.1
Reverse	AACTGTCTTGCACCAATGGCGA			
Lactobacillus casei				
Forward	AACTGTTGTCGGCGTGACGGTA	172	58	NR_041893.1
Reverse	GATGCGCTTCCTCGGTTAAGC			
Porphyromonas gingivalis				
Forward	GACCAGACTCCTACGGGAGGCA	222	58	NR_114574.1
Reverse	CCGGATAACGCTCGCATCCTC			

technology. Individuals can see which areas they brush for how long by downloading an app to their phone. The application directs the user to other areas when one area is brushed for a sufficient time.

All participants were given the same toothpaste (Colgate Triple Action, Colgate-Palmolive, China). It was a standard paste with a fluoride content of 1450 ppm and no additional specific ingredients.

The duration of the current study was set as 12 weeks. Saliva samples and periodontal index measurements were obtained from each participant three times: at the beginning of the research (T0) and at weeks 6 (T1) and 12 (T2). Periodontal index measurements and saliva collection were performed by a single researcher (T.E.). Because the current study was designed as an examiner-blinded study [26], toothbrush delivery and hygiene training were carried out by a different clinician (M.Ş).

The modified Bass tooth brushing technique was verbally explained to group 1 patients, and a YouTube video demonstrating the technique was shown. Individuals in group 2 were also provided information regarding the brushing process and device, both verbally and visually via YouTube video. All parts of the power brush (head, body, charger, and phone holder) were introduced. They were instructed to use the power brush in 'daily clean' mode. The patients were instructed to use only the provided brush and paste and were warned not to use any other oral care products (no different brush or different toothpaste and no mouthwash).

Plaque index (PI), gingival index (GI), and bleeding on probing (BOP) index were measured at T0, T1, and T2. Vestibule surfaces plaque scoring was done with the modified Quigley–Hein index (MQH) and lingual surfaces plaque scoring was done with the Turesky-modified Quigley–Hein index (TMQHPI). For the plaque scoring, the patients were asked to chew the Mira-2-Ton tablet (Hager Werken, Duisburg, Germany) for 1 min, spread it on all surfaces of the teeth with the tongue after chewing, and spit out the agent remaining in the mouth. After staining, all teeth were lightly air-dried, and the vestibule and lingual surfaces were scored from 0 to 5.

The Löe Silness gingival index was used to assess the degree of gingival inflammation caused by plaque. The teeth and gingiva were gently dried with air. The gingival index of each examined tooth was determined. Similarly, for six regions, the BOP index was evaluated to determine whether or not bleeding surfaces existed (+, –).

Saliva samples were collected from all patients at T0, T1, and T2. Patients were scheduled for morning appointments, and they were informed to not eat, drink, or brush their teeth for at least 2 h beforehand. The saliva samples were collected prior to periodontal evaluation. Each patient gave 3–4 ml saliva samples in a sterile container. Unstimulated saliva samples were taken twice, once for analysis and once as a backup. The container was labeled with the patients' information and the sampling time. The samples were transported under cold chain to the Afyonkarahisar Kocatepe University Veterinary Faculty Genetics Laboratory for microbiological analysis. Samples were stored at –80 °C until microbiological evaluation.

S. mutans, L. casei, and *P. gingivalis* bacteria were analyzed in saliva samples. DNA isolation and real-time PCR were performed on the samples, respectively. Applied Biosystems ViiA™ 7 (Life Technologies Corporation, Thermo Fisher Scientific, Waltham, MA, USA) PCR device was used for microbial analysis. The 96-well plate (VWR, Radnor, PA, USA) used to prepare the PCR mix was sealed with ultra-clear sealant film (Axygen, Union City, CA, USA). RealQ Plus 2x Master Mix Green, Low Rox kit (Ampliqon, Copenhagen, Denmark) was used during the real-time PCR process. The primer-forward and primer-reverse sequences for PCR analysis were created using the computer program FastPCR Professional 6.1.2 beta 2 (Table 1).

The levels of target DNA were determined using the PCR software's logarithmic curve drawn in response to fluorescent light. The Cq values were used to calculate the density of *S. mutans, L. casei*, and *P. gingivalis* bacteria in each

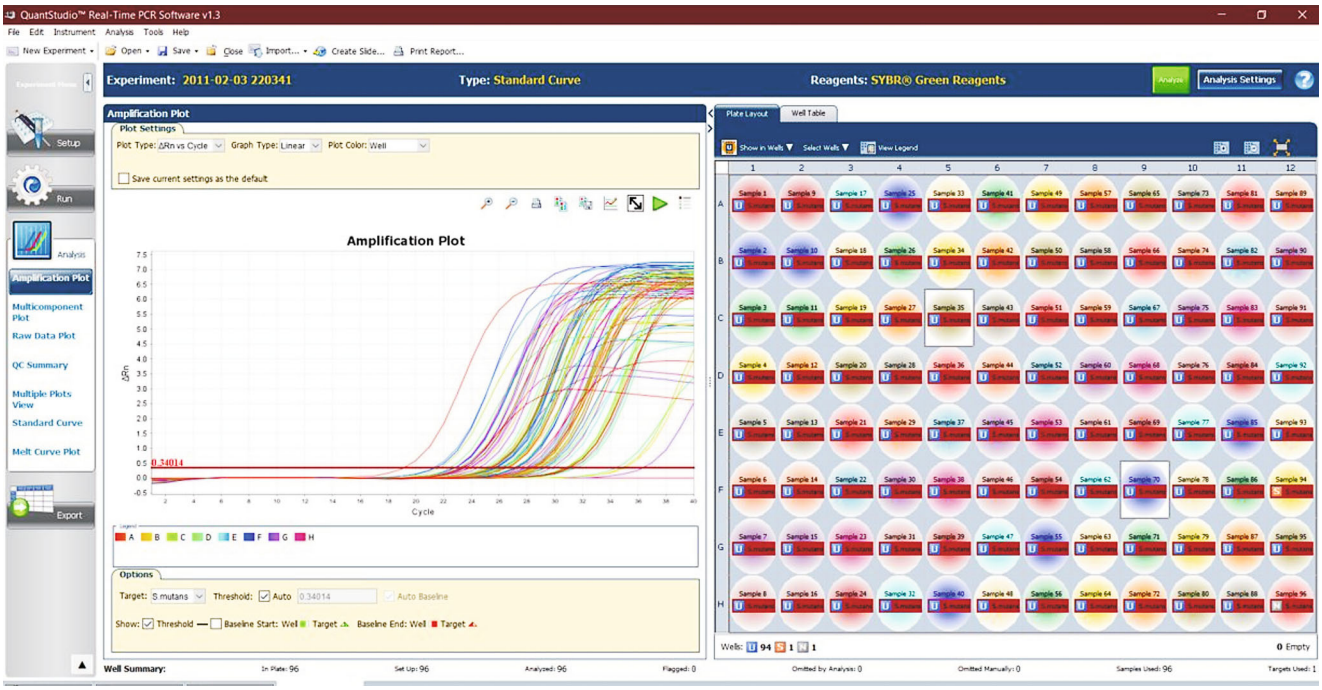

Fig. 1 *S. mutans* amplification curve
Abb. 1 *S.-mutans*-Amplifikationskurve

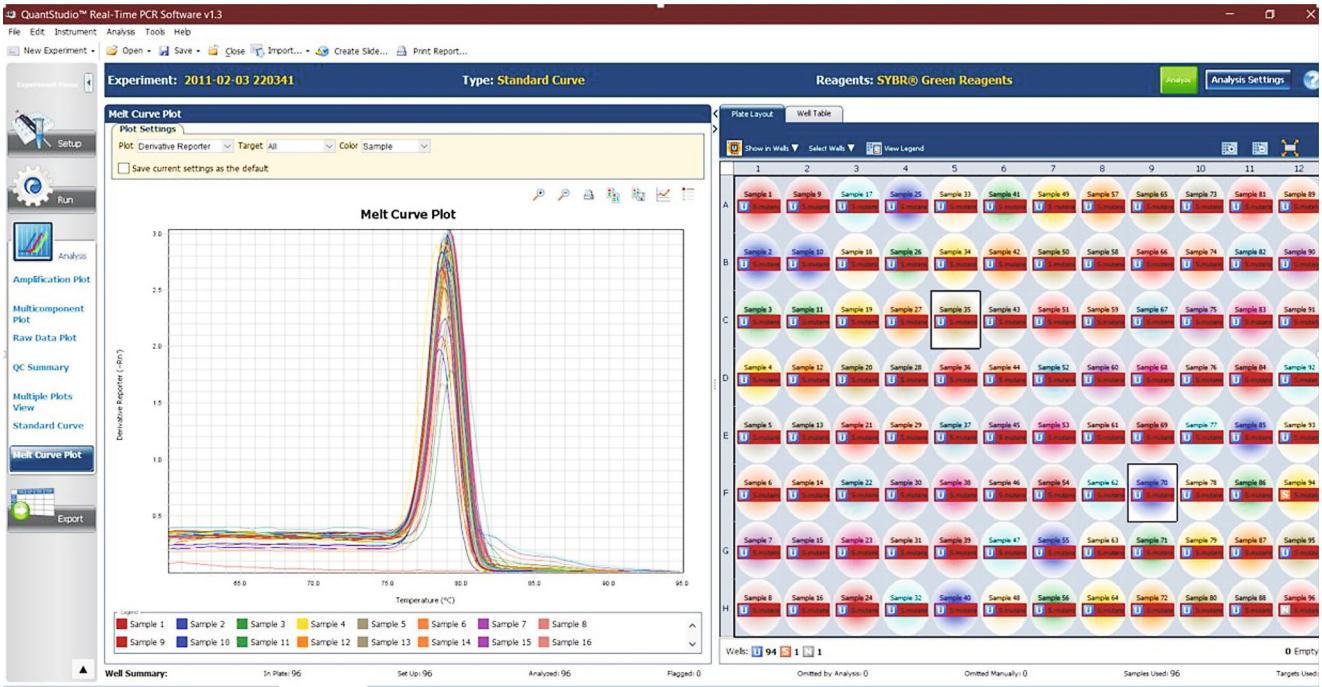

Fig. 2 Melting curve analysis of *S. mutans*
Abb. 2 Schmelzkurvenanalyse von *S. mutans*

sample. Bacterial numbers were calculated using a sample with a known copy number. By submitting this sample to a serial dilution lowering by 1/2, values for each parameter were calculated. All calculations were made using Quant Studio Real Time PCR Software v1.3 (Fig. 1). After the PCR process was completed, a melting curve analysis was performed to see whether there was any foreign DNA contamination or primer dimers in the PCR reaction (Fig. 2).

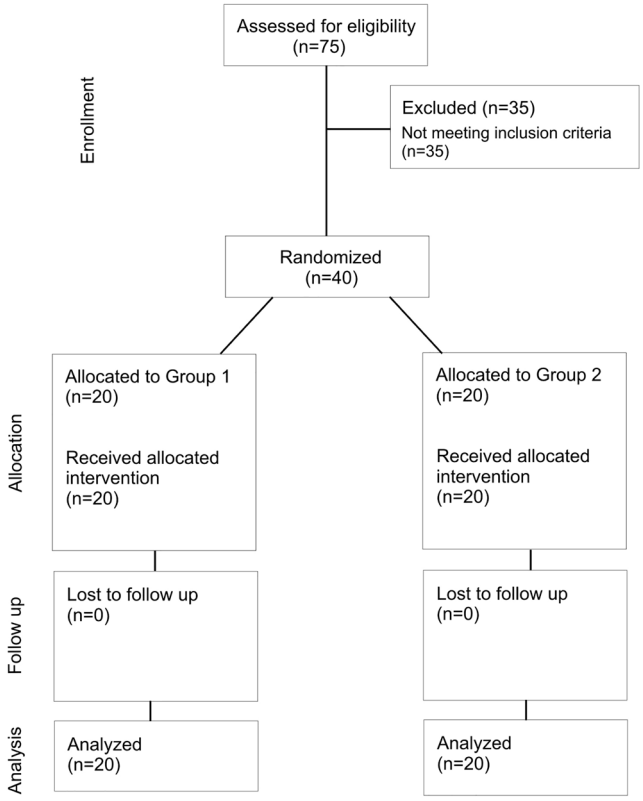

Fig. 3 Flowchart of the current study
Abb. 3 Ablaufdiagramm der aktuellen Studie

Objectives

The aim of the study was to assess the impact of Bluetooth-enabled IPTB and MOTB on oral hygiene in patients undergoing fixed orthodontic treatment, both clinically and microbiologically, utilizing periodontal index measures and real-time PCR.

Interim analyses and stopping guidelines

Not applicable.

Statistical analysis

The mean, standard deviation, minimum, and maximum of all parameters were calculated. The Shapiro–Wilk test was used to check the normality assumptions of continuous variables. For intergroup comparisons, the Mann–Whitney U test and independent samples t-test were used. For intragroup comparison of T0, T1, and T2 data, one-way analysis of variance (ANOVA), post hoc Friedman test, or Bonferroni test were used. In all analyses, the SPSS software (version 25, IBM, Armonk, NY, USA) was utilized, and the level of significance was set at $p < 0.05$.

Results

Participant flow

The study was conducted on 40 patients (20 females, 20 males; mean age 15.39 ± 1.68 years). During the research, no patients were excluded. The flowchart of the study is shown in Fig. 3.

Baseline data

There was no statistically significant difference between the mean age of the groups. The mean age of female and male participants was also similar (Table 2).

Numbers analyzed for each outcome

Intragroup and intergroup comparison results of plaque index scores are shown in Table 3. At T0, there was no statistically significant difference in plaque scores between the groups ($p = 0.632$); group 1 plaque scores, on the other hand, were higher at T1 ($p = 0.01$) and T2 ($p = 0.010$). Plaque scores were found to decrease gradually from T0 to T2 in both groups.

No difference was observed between the groups in terms of gingival index scores at T0, T1, and T2 (Table 4). How-

Table 2 Comparison of patient ages by group and gender
Tab. 2 Patientenalter, Vergleich nach Gruppe und Geschlecht

Gender	Female			Male			
	n	Mean ± SD	Median (Min–Max)	*n*	Mean ± SD	Median (Min–Max)	*p**
Group							
Group 1	10	15.52 ± 1.55	15.30 (12.80–17.50)	10	15.49 ± 1.41	15.40 (13.40–17.50)	0.912
Group 2	10	14.69 ± 2.98	14.45 (12.30–17.50)	10	15.86 ± 1.63	16.70 (12.90–17.50)	0.218
*p**	0.393			0.529			–

SD standard deviation, *Min* minimum, *Max* maximum, *Group 1* Manual toothbrush, *Group 2* Power toothbrush
*$p < 0.05$
*Mann–Whitney U test

Table 3 Comparison of plaque index scores
Tab. 3 Vergleich der Plaqueindexwerte

Groups	T0		T1		T2			
	Mean ± SD	Median (Min–Max)	Mean ± SD	Median (Min–Max)	Mean ± SD	Median (Min–Max)	p**	Difference between groups
Group 1	3.56 ± 0.42	3.57 (2.54–4.17)^{Aa}	2.94 ± 0.42	3.05 (2.25–3.65)^{Ab}	2.68 ± 0.37	2.65 (2.02–3.60)^{Ac}	< 0.001	b < a; c < a; c < b
Group 2	3.49 ± 0.50	3.54 (2.38–4.73)^{Aa}	2.44 ± 0.43	2.40 (1.33–3.27)^{Bb}	2.39 ± 0.33	2.36 (1.85–3.08)^{Bc}	< 0.001	b < a; c < a
p*	0.632		0.001		0.010		–	–

Lowercase superscripts represent differences in rows, whereas uppercase superscripts represent differences in columns
SD standard deviation, *Min* minimum, *Max* maximum, *T0* beginning of the study, *T1* 6th week, *T2* 12th week, *Group 1* Manual toothbrush, *Group 2* Power toothbrush
*Independent sample t-test ($p < 0.05$)
**One-way analysis of variance (post hoc Bonferroni $p < 0.017$)

Table 4 Comparison of gingival index scores
Tab. 4 Vergleich der Gingivaindexwerte

Groups	T0		T1		T2			
	Mean ± SD	Median (Min–Max)	Mean ± SD	Median (Min–Max)	Mean ± SD	Median (Min–Max)	p**	Difference between groups
Group 1	1.60 ± 0.19	1.57 (1.31–1.90)^{Aa}	1.33 ± 0.12	1.33 (1.15–1.58)^{Ab}	1.29 ± 0.11	1.27 (1.14–1.51)^{Ac}	< 0.001	b < a; c < a; c < b
Group 2	1.62 ± 0.19	1.61 (1.22–2.00)^{Aa}	1.36 ± 0.14	1.32 (1.17–1.65)^{Ab}	1.29 ± 0.13	1.28 (1.12–1.56)^{Ac}	< 0.001	b < a; c < a; c < b
p*	0.738		0.738		0.799		–	–

Lowercase superscripts represent differences in rows, whereas uppercase superscripts represent differences in columns
SD standard deviation, *Min* minimum, *Max* maximum, *T0* beginning of the study, *T1* 6th week, *T2* 12th week, *Group 1* Manual toothbrush, *Group 2* Power toothbrush
*Mann–Whitney U test ($p < 0.05$)
**Friedman (post hoc Bonferroni $p < 0.017$)

Table 5 Comparison of bleeding on probing index results
Tab. 5 Vergleich der Blutungsindexwerte

Groups	T0		T1		T2			
	Mean ± SD	Median (Min–Max)	Mean ± SD	Median (Min–Max)	Mean ± SD	Median (Min–Max)	p**	Difference between groups
Group 1	59.69 ± 19.41	56.60 (24.31–90.28)^{Aa}	33.13 ± 12.21	33.33 (14.58–57.64)^{Ab}	29.17 ± 11.01	27.78 (13.89–52.08)^{Ac}	< 0.001	b < a; c < a
Group 2	59.51 ± 19.74	60.76 (18.06–95.14)^{Aa}	35.97 ± 14.60	31.94 (16.67–64.58)^{Ab}	28.75 ± 13.42	28.13 (11.81–56.25)^{Ac}	< 0.001	b < a; c < a; c < b
p*	0.925		0.698		0.779		–	–

Lowercase superscripts represent differences in rows, whereas uppercase superscripts represent differences in columns
SD standard deviation, *Min* minimum, *Max* maximum, *T0* beginning of the study, *T1* 6th week, *T2* 12th week, *Group 1* Manual toothbrush, *Group 2* Power toothbrush
*Mann–Whitney U test ($p < 0.05$)
**Friedman (post hoc Bonferroni $p < 0.017$)

ever, it was observed that gingival index scores decreased gradually from T0 to T2 in both groups.

No significant difference was observed between the groups in terms of BOP scores at T0, T1, and T2 (Table 5). The BOP scores, on the other hand, decreased gradually from T0 to T2 in both groups.

At T0, the level of *S. mutans* in group 2 was significantly greater than in group 1 ($p = 0.021$). However, there was no significant difference between the groups at T1 ($p = 0.199$). At T2, the level of *S. mutans* in group 2 was once again greater than that in group 1. The change in time intervals in both groups, however, was not statistically significant (Table 6).

At T0 and T2, no significant difference in *P. gingivalis* level was observed between groups 1 and 2. However, it was lower in group 1 at T1. The *P. gingivalis* level decreased

Table 6 *Streptococcus mutans* (cfu/ml) intergroup and intragroup comparison
Tab. 6 *Streptococcus mutans* (cfu/ml), Inter- und Intragruppenvergleich

Groups	T0		T1		T2			
	Mean ± SD	Median (Min–Max)	Mean ± SD	Median (Min–Max)	Mean ± SD	Median (Min–Max)	p**	Difference between groups
Group 1	6.30 ± 11.08	2.58 (0.02–40.09)^{Aa}	6.38 ± 11.98	1.54 (0.00–41.01)^{Aa}	5.77 ± 10.31	1.22 (0.04–37.09)^{Aa}	0.157	–
Group 2	50.11 ± 143.03	8.29 (0.19–648.81)^{Aa}	13.52 ± 24.51	3.48 (0.07–103.22)^{Aa}	16.67 ± 28.89	7.11 (0.01–129.9)^{Ba}	0.058	–
p*	0.021		0.199		0.045		–	–

The mean, median, and standard deviation values should be multiplied by 10^5 to provide corrected values. Lowercase superscripts represent differences in rows, whereas uppercase superscripts represent differences in columns
SD standard deviation, *Min* minimum, *Max* maximum, *T0* beginning of the study, *T1* 6th week, *T2* 12th week, *Group 1* Manual toothbrush, *Group 2* Power toothbrush
*Mann–Whitney U test ($p < 0.05$)
**Friedman (post hoc Bonferroni $p < 0.017$)

Table 7 *Porphyromonas gingivalis* (cfu/ml) intergroup and intragroup comparison
Tab. 7 *Porphyromonas gingivalis* (cfu/ml), Inter- und Intragruppenvergleich

Groups	T0		T1		T2			
	Mean ± SD	Median (Min–Max)	Mean ± SD	Median (Min–Max)	Mean ± SD	Median (Min–Max)	p**	Difference between groups
Group 1	4.09 ± 5.31	1.74 (0.04–19.66)^{Aa}	1.39 ± 1.90	0.87 (0.12–8.29)^{Ab}	2.19 ± 2.48	1.13 (0.21–10.57)^{Ac}	0.002	b < a; b < c
Group 2	5.18 ± 4.91	3.61 (0.51–19.05)^{Aa}	1.84 ± 1.36	1.37 (0.19–5.25)^{Bb}	3.87 ± 3.70	2.43 (0.31–13.52)^{Ac}	0.002	b < a; b < c
p*	0.152		0.048		0.079		–	–

The mean, median, and standard deviation values should be multiplied by 10^5 to provide corrected values. Lowercase superscripts represent differences in rows, whereas uppercase superscripts represent differences in columns
SD standard deviation, *Min* minimum, *Max* maximum, *T0* beginning of the study, *T1* 6th week, *T2* 12th week, *Group 1* Manual toothbrush, *Group 2* Power toothbrush
*Mann–Whitney U test ($p < 0.05$)
**Friedman (post hoc Bonferroni $p < 0.017$)

Table 8 *Lactobacillus casei* (cfu/ml) intergroup and intragroup comparison
Tab. 8 *Lactobacillus casei* (cfu/ml), Inter- und Intragruppenvergleich

Groups	T0		T1		T2			
	Mean ± SD	Median (Min–Max)	Mean ± SD	Median (Min–Max)	Mean ± SD	Median (Min–Max)	p**	Difference between groups
Group 1	1.99 ± 4.39	0.13 (0.00–18.65)^{Aa}	2.22 ± 6.69	0.18 (0.00–29.79)^{Aa}	0.87 ± 1.87	0.17 (0.00–7.34)^{Aa}	0.350	–
Group 2	1.70 ± 2.94	0.25 (0.00–10.94)^{Aa}	0.45 ± 1.10	0.02 (0.00–4.62)^{Ab}	0.67 ± 1.69	0.05 (0.00–7.24)^{Ac}	0.006	b < a; c < a
p*	0.534		0.083		0.323		–	–

The mean, median, and standard deviation values should be multiplied by 10^5 to provide corrected values. Lowercase superscripts represent differences in rows, whereas uppercase superscripts represent differences in columns
SD standard deviation, *Min* minimum, *Max* maximum, *T0* beginning of the study, *T1* 6th week, *T2* 12th week, *Group 1* Manual toothbrush, *Group 2* Power toothbrush
*Mann–Whitney U test ($p < 0.05$)
**Friedman (post hoc Bonferroni $p < 0.017$)

from T0 to T1, but increased from T1 to T2 in both groups (Table 7).

There was no statistically significant difference in *L. casei* level between groups at T0, T1, or T2 (Table 8). The difference that occurred at different time intervals in group 1 was not statistically significant, but it was in group 2.

Harm

No harm was observed in any participant during the trial.

Discussion

Main findings regarding evidence and interpretation

Traditional oral hygiene procedures are made more difficult by fixed orthodontic treatment, which also increases the number of plaque retention zones, raising the risk of cavities and gingival inflammation [27]. Plaque and salivary flora change rapidly when orthodontic appliances are placed in the mouth [28].

There are numerous studies evaluating the plaque removal efficiency of toothbrushes (such as manual orthodontic brushes, three-headed brushes, conventional brushes, and brushes with various types of bristles) used in patients with fixed orthodontic appliances in the literature [29]. The researchers were unable to achieve an agreement due to the discrepancy in their findings. In a systematic review and meta-analysis study by ElShehaby et al. [30], in which they compared the effectiveness of power and manual brushes, it was concluded that a well-designed randomized controlled study is needed on this topic.

It has been claimed that smart phone applications and active reminders, as a result of technological advancements, can improve the oral hygiene of orthodontic patients [31]. The smartphone application used in the current study allowed the patients to see information such as brushed area and brushing time.

Saliva composition has been implicated as a potential biomarker of oral health status [32]. Individuals' plaque and saliva samples were taken in one study, and microbiological assessment was performed. The researchers concluded that there was no difference in the bacterial content of plaque and saliva. They claimed that saliva samples may be preferred because the bacterial composition of the plaque varies depending on the location in the mouth [33].

The real-time PCR method has advantages such as high technical sensitivity and precision, no additional post-PCR steps, less risk of cross-contamination, and shorter detection times. Real-time PCR, on the other hand, detects and quantifies nucleic acids from both living and dead pathogens, whereas traditional microbiological tests only count viable pathogens. In a study comparing traditional culture and real-time PCR diagnostic methods, Jerve-Storm et al. observed that real-time PCR is more sensitive in detecting periodontal pathogens [34].

There was no significant difference between the two groups' initial periodontal index values in the current study. This suggests that the participants in the study had similar levels of oral hygiene routines. Intragroup plaque index, gingival index, and BOP index values decreased significantly in both groups during the T0–T1 and T0–T2 time intervals. These findings, according to the study's authors, can be attributed to the oral hygiene education offered at the beginning of this study, as well as the Hawthorne effect [35]. Heasman et al. evaluated the participants' periodontal index values at the time when they chose the patients to participate in the study and when the toothbrushes were delivered 2 weeks later [36]. As a result, the plaque index scores were found to be significantly lower, despite the fact that the toothbrushes had not yet been distributed and the study had not yet begun. The Hawthorne effect, according to the researchers, was responsible for the decrease in plaque score. In similar studies, Ay et al. [37] and Ousheal et al. [38] reported a decrease in periodontal index scores of participants.

In the intergroup comparison, periodontal index scores were found to be significantly lower in group 2 at T0–T1 (1.03 ± 0.45), T0–T2 (1.10 ± 0.41), and T1–T2 (0.06 ± 0.38) time intervals. However, there was no significant difference in gingival index and BOP index scores between the two groups at T0–T1 (0.18 ± 0.35), T0–T2 (2.84 ± 2.41), and T1–T2 time intervals (1.58 ± 2.41). In line with the current study findings, some studies in the literature claim that the power toothbrush is more effective at removing plaque [26, 38, 39]. Some researchers, however, suggest that there is no difference between manual and power toothbrushes [25, 40, 41].

In the current study, it was observed that there was no clear correlation between the numbers of *S. mutans, L. casei*, and *P. gingivalis* and periodontal index scores. In other words, in patients receiving fixed orthodontic treatment, the numbers of *S. mutans, L. casei,* and *P. gingivalis* may not decrease in direct proportion to periodontal index score reduction. Furthermore, the variation of bacteria in the T0, T1, and T2 time intervals revealed a nonlinear distribution (e.g., group 2 *P. gingivalis* level: T0: 5.18 ± 4.91 cfu/ml, T1: 1.84 ± 1.36 cfu/ml, T2: 3.87 ± 3.70 cfu/ml). Cildir et al. found that probiotic yogurt consumption affected salivary *S. mutans* and *L. casei* levels in orthodontic patients [42]. Jeon et al. conducted microbiological assessments both before and after the bonding session, and it was revealed that the total bacterial amount, particularly streptococcus and anaerobic periodontal pathogenic bacteria, increased [43]. Brushing frequency, according to Peros et al., reduced the number of *S. mutans* but had no effect on the amount of lactobacillus. The variability of similar studies' findings could be explained by other factors influencing salivary bacteria composition and different research methods. Diet, lack of water consumption, vitamin D deficiency, changes in hormones such as ADH (antidiuretic hormone), aldosterone, testosterone, thyroxine, and stress can all affect the amount of saliva secretion in the mouth. Salivary antibacterial enzymes in the mouth are reduced as a result of a decrease in saliva. Saliva's washing effect and buffering capacity may also be reduced. Changes in the amount and composition

of saliva can have an impact on the bacterial flora of the mouth.

Limitations

One limitation of the current study is that only a few specific bacterial species were evaluated. Furthermore, bacterial content in saliva samples may be affected by diet, but diet was not restricted or regulated. Other limitations are the relatively short duration of the experiment and the small sample size.

Generalizability

The study's findings revealed that interactive power toothbrushing (IPTB) provides better plaque removal. However, there was no precise correlation between gingival index and plaque scores. Similarly, there was no clear relationship between plaque scores and salivary bacteria content. As a result, the findings of this 3-month study on a small number of patients could not be generalized.

Conclusions

- The interactive power brush was more effective at removing plaque than the manual brush.
- The results of the gingival index, on the other hand, did not reflect the plaque scores.
- The number of certain salivary bacteria and brush type did not appear to have a clear relationship.

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Declarations

Conflict of interest T. Erden and H. Camcı declare that they have no competing interests.

Ethical standards This study was approved by Afyonkarahisar Health Science University Clinical Research Ethics Committee (ID: 2020/488). Written consent for publication was obtained from each participant.

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