Journal of Chemical Health Risks

www.jchr.org

JCHR (2024) 14(3), 1297-1306 | ISSN:2251-6727

Effectiveness of New Activated Charcoal Orthodontic Toothbrush on Plaque Removal in Orthodontic Patients Using Orthodontic Plaque Index and Gingival Index: A Randomized Cross-Over Study

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(Received: 04 February 2024 Revised: 11 March 2024 Accepted: 15 May 2024)

KEYWORDS
charcoal, orthodontic, toothbrush, plaque, gingival index, plaque index

ABSTRACT:
Background: This study was conducted to assess the Effectiveness Of New Activated Charcoal Orthodontic Toothbrush On Plaque Removal In Orthodontic Patients Using Orthodontic Plaque Index And Gingival Index: A Randomized Cross-Over Study.
Material and methods: A small-scale study (pilot study) was conducted beforehand to assess the practicality of carrying out the main research. This preliminary investigation examined key areas such as the ease of recruiting participants, the effectiveness of data collection methods, and whether participants would follow the study guidelines. The pilot study's results demonstrated alignment with the main study's intentions and objectives, hence proceed with the full-fledged research.
Results: When intra-brush comparison was made for the observation period of complete six weeks, i.e., T0-T3, for the 60 patients having three types of brushes (Table 4). For brush I, there was an overall improvement in the mean gingival index from baseline to T3 (0.138±0.404, p-value=0.010) that was significant, while significant improvement was seen at all the intervals except for T1 to T2 (-0.088±0.144, p-value=0.000). At all the intervals no significant difference was observed in Eastmann interdental bleeding index. Also, there was an overall significant improvement in the mean OPI score from T0 to T3 (0.267±0.972, p-value=0.038). However, a significant improvement was seen at only T0 to T1 (0.300±1.078, p-value=0.035). For Brush II, on the contrary, no significant change in the mean gingival index was seen at any observation interval. When the mean Eastmann bleeding index was observed, there was a significant improvement from T0 to T3

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(0.367±1.262 p-value=0.028), where significant improvement was seen at only T2-T3 (0.300±1.046, p-value=0.030).
Conclusion: Intragroup observation showed that the charcoal-activated v-cut toothbrush significantly reduced plaque and improved gingival health over six weeks of observation. More reduction was seen in the initial phases, showing its effectiveness in controlling orthodontic patients' oral hygiene. The conventional orthodontic toothbrush significantly reduced plaque and improved gingival health over six weeks of observation, showing its effectiveness in controlling oral hygiene in orthodontic patients. The charcoal-activated flat-cut toothbrush significantly reduced plaque and improved gingival health over six weeks of observation, showing its effectiveness in controlling oral hygiene in orthodontic patients. The charcoal-activated V-cut toothbrush showed the highest efficiency in plaque reduction, followed by conventional orthodontic toothbrushes and charcoal-activated flat-cut toothbrushes in orthodontic patients. However, no significant difference between the three was found.

Introduction

Orthodontic treatment has become increasingly popular in recent years, with more individuals seeking it for either aesthetic or functional reasons. This surge in demand is attributed to greater awareness of orthodontic options and improved accessibility to these treatments. While orthodontic procedures can be highly beneficial in achieving ideal occlusion and enhancing a patient's appearance, they do come with certain challenges, particularly in terms of maintaining oral hygiene over an extended period. One of the primary motivations for undergoing orthodontic treatment is to improve one's smile and overall facial aesthetics. Crooked or misaligned teeth can significantly impact a person's self-esteem and confidence. Furthermore, orthodontic treatment can correct functional issues, such as improper bites, which can lead to problems with speech, eating, and overall oral health. As a result, more people are choosing orthodontic procedures to enhance both their appearance and oral functionality.[(1)]

It's important for patients to communicate any periodontal concerns they may have with their orthodontist. With this information in hand, the orthodontist can make informed decisions regarding the tooth movements and adjustments required during the treatment process. This proactive approach can lead to improved periodontal health outcomes, making orthodontic therapy not just a cosmetic endeavour but a holistic approach to enhancing both the appearance and health of the smile. [(2)]

For an outline, orthodontic treatment offers a wide range of benefits beyond just straightening teeth. It can address periodontal issues, enhance aesthetics, and provide important preparatory steps for various dental procedures, ultimately contributing to improved oral health and overall well-being. Despite the potential long-term health benefits that orthodontic treatment can offer, the process itself presents challenges for patients. A sticky layer of bacteria, called plaque, builds up on teeth. It consists of a complex matrix of microorganisms embedded in a polymer matrix. Plaque buildup is a natural occurrence, but in the context of orthodontic treatment, there are more opportunities for plaque retention. This is primarily due to the presence of orthodontic brackets, which create areas that trap plaque and hinder effective tooth cleaning. Dental plaque is a key contributor to oral health problems, making its removal and management crucial for maintaining good oral health. Failure to address plaque buildup can result in enamel damage and gum inflammation. [(3)]

Previous research has highlighted that individuals undergoing orthodontic treatment are more susceptible to enamel demineralization compared to those without such treatment. In fact, as many as half of the teeth treated with brackets and up to half of all orthodontic patients have reported the development of white spots on their teeth as a consequence of this plaque-related issue.[(4)]

However, the prolonged duration of orthodontic treatment can pose challenges when it comes to maintaining good oral hygiene. [(5)]

White spots on teeth can appear when plaque lingers on the enamel for too long. This loss of minerals in the enamel, unlike natural variations in tooth development, weakens the tooth. This distinction is based on factors

Journal of Chemical Health Risks
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JCHR (2024) 14(3), 1297-1306 | ISSN:2251-6727

such as where they appear on the tooth, their shape, and whether they change in size over time. However, in cases where this developmental irregularity occurs near the gumline (labiogingival area), it can sometimes be mistaken for demineralization.

Among the teeth studied by Gorelick et al.[4] , revealed that the maxillary lateral incisors had the highest incidence of decalcification, occurring in twenty one percent of cases. This rate was nearly three times higher than that observed for the central incisors. Moreover, the maxillary and mandibular canines and premolars showed a significant prevalence of white spots. Interestingly, teeth treated with either bands or bonds for a relatively short period (twelve to sixteen months) exhibited a similar occurrence of white spots compared to those undergoing longer treatment durations, up to 36 months.

Unlike other dental procedures, orthodontic treatments often span several months to a few years. During this time, patients must contend with fixed appliances like braces or retainers, which can make thorough cleaning more difficult. These appliances create more surfaces where dental plaque can accumulate, leading to potential oral health issues. Plaque buildup is a natural occurrence, but in the context of orthodontic treatment, there are more opportunities for plaque retention.[6] The brackets, wires, and other components of orthodontic appliances create nooks and crannies where food particles and plaque can become trapped. This can result in an increased risk of dental issues like tooth decay, gum disease, and bad breath. Therefore, individuals undergoing orthodontic treatment must be particularly diligent in their oral hygiene practices. Dentists and orthodontists often provide guidance on proper cleaning techniques and may recommend special tools like interdental brushes or water flossers to help patients maintain a high level of oral hygiene.[7]

Over 300 years have passed since van Leeuwenhoek's initial discovery of "animalcules" in tooth scrapings, yet the intricate structure and biological functions of the bacterial community residing within the human teeth continue to be a subject of ongoing investigation. It was Black who first characterized the gel-like microbial plaque that forms on tooth surfaces due to the accumulation of a multitude of different species. These species inhabit this distinct ecological environment within the oral cavity, a discovery that had previously been noted by scientists like Miller and Williams. Despite centuries of research, unraveling the complexities of this bacterial community and its interactions with our teeth remains an ongoing scientific endeavor. The structure and composition of plaque were extensively studied during the period of descriptive biology. Within biofilms like dental plaque, there are many interactions taking place between different bacteria and between bacteria and the host. Among these interactions, the ones that are particularly significant involve the adhesion of bacteria to the tooth surface. These adhesion interactions play a crucial role in anchoring the bacteria in place and stabilizing the three-dimensional structure of the plaque matrix.[8]

Research on dental plaque has provided clear insights into the progression of microorganisms within it. Streptococci are identified as the predominant "pioneer" species in the early stages of plaque formation. As plaque develops further, there is a gradual increase in the presence of actinomyces. Ultimately, as the plaque matures, it transforms into a community dominated by high levels of Gram-negative anaerobic filamentous organisms (*Figure 2*). This understanding of the sequential changes in microbial composition within dental plaque is essential in comprehending oral health and the development of strategies to manage and prevent dental issues associated with plaque formation.[9]

Not enough research on the efficacy of charcoal-infused toothbrushes or orthodontic toothbrushes has been published. To have better and more predictable outcomes of orthodontic treatment, this study may prove to be of assistance and patient acceptance towards having good oral hygiene. This research aims to investigate whether toothbrushes with charcoal-infused bristles can be more effective for people with braces (orthodontic patients). These brushes could potentially improve oral hygiene, particularly for those undergoing orthodontic treatment.

Material and methods

A small-scale study (pilot study) was conducted beforehand to assess the practicality of carrying out the main research. This preliminary investigation examined key areas such as the ease of recruiting participants, the effectiveness of data collection methods, and whether participants would follow the study guidelines. The pilot study's results demonstrated alignment with the main

Journal of Chemical Health Risks
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JCHR (2024) 14(3), 1297-1306 | ISSN:2251-6727

study's intentions and objectives, hence proceed with the full-fledged research.

INCLUSION CRITERIA:

- Patients age range between 12 to 30 years
- A fair oral hygiene simplified index (1.3-3.0) at the time of inclusion.
- No history of taking steroids, antibiotics, or NSAIDs in the past two months.
- Patients with good dexterity and compliance.
- Manual toothbrush user.
- Patients having no history of allergies to food dyes (especially Erythrosine FDC Red 3)

EXCLUSION CRITERIA:

- Patients using antibacterial mouth rinses.
- Powered toothbrush user
- Patients with smoking and chewing tobacco habits.
- Presence of any local or systemic disease, immunosuppressant drug therapy, or Pregnant female.
- Have you taken any steroids, antibiotics, or pain medication (like ibuprofen or aspirin) in the last two months.
- Mentally challenged patients
- Subjects with poor neuromuscular coordination.
- Patients with poor compliance
- Patients with a history of allergies to food dyes (especially Erythrosine FDC Red 3)

DISCONTINUATION CRITERIA

- Patient not maintaining the records of brushing.
- Patient not reporting on the date of evaluation.

METHODOLOGY

Detailed method

Selected 60 patients as per the inclusion and exclusion criteria, explained the study procedure, and was asked to sign the written consent form according to institution rules and regulations.

The participants were randomly assigned to one of three groups, each using a different type of brush.

Brush I: Charcoal-activated V-cut orthodontic toothbrush. (PurexaTM)

Brush II: Conventional orthodontic toothbrush. (ColgateTM)

Brush III: Charcoal-activated flat bristle toothbrush. (Datun IndiaTM)

- The patients received detailed instructions on how to clean their teeth properly, including the bass brushing technique. To help them visualize the process, the dentist demonstrated it on models with upper and lower braces.
- All the patients were instructed to brush twice daily (once in the morning after breakfast for a 2-minute time and once before retiring to bed with the same allotted toothbrush for a period of 2 minutes)
- In addition to the instructions, patients received a mobile app timer, a printed toothbrushing booklet with detailed steps, and a personal planner to track their brushing routine.
- A trial period of 1 week to check their compliance with the instructions and study.
- Compliant patients were given oral prophylaxis to commence the study at the gingival index of Mild gingivitis (0.1-1.0).
- Study was done in 3 phases with a cross-over design which is depicted in Figure 15.
- Eastman interdental bleeding index and Gingival index recorded before in-office brushing. In contrast, recording of orthodontic plaque index was done before and after toothbrushing in the office in the orthodontic department clinic.
- Record taking was done on second week-$\mathbf{T_1}$ after prophylaxis, fourth week-$\mathbf{T_2}$, and sixth week visit-$\mathbf{T_3}$ after allotment of toothbrush.
- Patients are advised not to use other oral hygiene maintenance devices and solutions

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(water flossers, mouthwashes, interdental brushes, etc.).

- Subjects were also asked not to brush for 12 hours before the evaluation appointment.
- This assessment focuses solely on teeth or areas where brackets are bonded to the front surface.
- Teeth-bearing orthodontic bands were omitted.
- The teeth's labial surface was divided into sextants (mesial, distal, occlusal/incisal, and cervical) for OPI record.

STATISTICAL ANALYSIS:

Data was analysed by SPSS statistical software (version 22.0; IBM, Armonk, NY). Paired T-test used to test the mean difference between two variables for the same subject at different times. Tukey post-hoc test was done to compare means of three independent groups to determine statistical evidence that the sample means are significantly different for the same variable.

Results

Intra-brush Comparison:

When intra-brush comparison was made for the observation period of complete six weeks, i.e., T0-T3, for the 60 patients having three types of brushes (Table 4).

For brush I, there was an overall improvement in the mean gingival index from baseline to T3 (0.138±0.404, p-value=0.010) that was significant, while significant improvement was seen at all the intervals except for T1 to T2 (-0.088±0.144, p-value=0.000). At all the intervals no significant difference was observed in Eastmann interdental bleeding index. Also, there was an overall significant improvement in the mean OPI score from T0 to T3 (0.267±0.972, p-value=0.038). However, a significant improvement was seen at only T0 to T1 (0.300±1.078, p-value=0.035).

For Brush II, on the contrary, no significant change in the mean gingival index was seen at any observation interval. When the mean Eastmann bleeding index was observed, there was a significant improvement from T0 to T3 (0.367±1.262 p-value=0.028), where significant improvement was seen at only T2-T3 (0.300±1.046, p-value=0.030). But non-significant change observed for the mean change in OPI score at any interval.

For Brush III, although a non-significant improvement of mean gingival index at T2-T3 (0.059±0.317, p-value= 0.155), an overall increase in the mean gingival index from T0 to T3 (-0.208±0.599, p-value=0.009). The level of bleeding measured by the Eastman Bleeding Index remained stable throughout the observation period that was statistically non-significant change. Similarly, non-significant change in the OPI score from T0-T3 (0.200±0.953, p-value=0.109) was seen, although a significant improvement in the mean OPI score was observed at T0-T1(0.367±0.938, p-value=0.004)

Table 4: Intra-brush Comparison of reduction in mean gingival index, bleeding index, and orthodontics plaque index by brush I, II, and III at T0 to T1, T1 to T2, T2 to T3 and in 6 weeks i.e., T0 to T3

Groups	Parameter	Interval	Mean Difference	Standard Deviation	p Value	Significance
Brush I	**Gingival Index**	**T0-T3**	**0.138**	**0.404**	**0.01**	**S**
		T0-T1	**0.039**	**0.146**	**0.042**	**S**
		T1-T2	**-0.088**	**0.144**	**0**	**S**
		T2-T3	**0.187**	**0.35**	**0**	**S**
	Eastmann Bleeding Index	T0-T3	0.333	1.434	0.077	NS
		T0-T1	0.033	0.823	0.755	NS
		T1-T2	0.283	1.303	0.097	NS

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		T2-T3	0.017	1.282	0.92	NS
	Mean OPI	**T0-T3**	**0.267**	**0.972**	**0.038**	**S**
		T0-T1	**0.3**	**1.078**	**0.035**	**S**
		T1-T2	-0.217	0.993	0.096	NS
		T2-T3	0.183	0.873	0.109	NS
Brush II	**Mean Gingival Index**	T0-T3	-0.055	0.499	0.399	NS
		T0-T1	-0.087	0.403	0.099	NS
		T1-T2	0.013	0.128	0.418	NS
		T2-T3	0.019	0.113	0.198	NS
	Eastmann Bleeding Index	**T0-T3**	**0.367**	**1.262**	**0.028**	**S**
		T0-T1	0.15	0.777	0.14	NS
		T1-T2	-0.083	1.078	0.552	NS
		T2-T3	**0.3**	**1.046**	**0.03**	**S**
	Mean OPI	T0-T3	-0.05	1.064	0.717	NS
		T0-T1	-0.067	1.191	0.666	NS
		T1-T2	-0.05	0.928	0.678	NS
		T2-T3	0.067	1.087	0.637	NS
Brush III	**Mean Gingival Index**	**T0-T3**	**-0.208**	**0.599**	**0.009**	**S**
		T0-T1	**-0.139**	**0.364**	**0.005**	**S**
		T1-T2	**-0.128**	**0.303**	**0.002**	**S**
		T2-T3	0.059	0.317	0.155	NS
	Eastmann Bleeding Index	T0-T3	-0.183	1.242	0.257	NS
		T0-T1	-0.167	0.827	0.124	NS
		T1-T2	-0.05	0.699	0.582	NS
		T2-T3	0.033	1.025	0.802	NS
	Mean OPI	T0-T3	0.2	0.953	0.109	NS
		T0-T1	**0.367**	**0.938**	**0.004**	**S**
		T1-T2	0.017	0.911	0.888	NS
		T2-T3	-0.183	0.792	0.078	NS

When intra-brush comparison was done for evaluating the change in the mean before brushing OPI score from baseline i.e. T0 to the six weeks i.e. T3 mean OPI score significantly improved for all the brushes. (Table 5)

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Table 5: Intra-Brush Comparison of reduction in mean OPI score before brushing over 6 weeks i.e., from T0 (Before) to T3 (Before)						
Brush	T0 (Before)	T3(Before)	T0-T3 (Mean Difference)	Standard Deviation	p-Value	Sig
Brush I	**3.333**	**2.683**	**0.650**	**0.936**	**0.000**	**S**
Brush II	**3.300**	**2.700**	**0.600**	**0.867**	**0.000**	**S**
Brush III	**1.118**	**0.910**	**0.400**	**0.995**	**0.003**	**S**

Inter-Brush Comparison:

When inter-brush comparison was made for the observation period of complete six weeks, i.e., T0-T3, for the 60 patients having three types of brushes, it was observed that there was a significant difference between the brush I and brush II also between Brush II and Brush III at all the intervals for mean gingival index change. However, no significant difference was observed for the mean Eastman bleeding index change and mean orthodontic plaque index change at any interval (Table 6).

Table 6: Inter-Brush Comparison of reduction in mean gingival index, bleeding index, and orthodontics plaque index by brush I, II, and III at T0 to T1, T1 to T2, T2 to T3 and in 6 weeks i.e., T0 to T3					
Parameter	**Interval**	**Brush Group**	**Mean Difference**	**Sig. Value**	**Sig.**
Gingival Index (n=60)	T0-T3	**I-II**	**0.257**	**0.006**	**S**
		II-III	**-0.327**	**0.000**	**S**
		III-I	0.069	0.732	NS
	T0-T1	**I-II**	**0.150**	**0.022**	**S**
		II-III	**-0.180**	**0.004**	**S**
		III-I	0.030	0.881	NS
	T1-T2	**I-II**	**-0.075**	**0.047**	**S**
		II-III	**0.115**	**0.001**	**S**
		III-I	-0.040	0.497	NS
	T2-T3	**I-II**	**0.183**	**0.002**	**S**
		II-III	**-0.263**	**0.000**	**S**
		III-I	0.079	0.386	NS
Eastmann Index (n=60)	T0-T3	I-II	-0.033	0.989	NS
		II-III	0.550	0.060	NS
		III-I	-0.517	0.083	NS
	T0-T1	I-II	-0.117	0.710	NS
		II-III	0.317	0.084	NS
		III-I	-0.200	0.368	NS
	T1-T2	I-II	0.367	0.141	NS
		II-III	-0.033	0.984	NS
		III-I	-0.333	0.198	NS
	T2-T3	I-II	-0.283	0.353	NS
		II-III	0.267	0.397	NS
		III-I	0.017	0.996	NS

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JCHR (2024) 14(3), 1297-1306 | ISSN:2251-6727

OPI (n=60)	T0-T3	I-II	0.317	0.194	NS
		II-III	-0.25	0.358	NS
		III-I	-0.067	0.929	NS
	T0-T1	I-II	0.367	0.151	NS
		II-III	-0.433	0.072	NS
		III-I	0.067	0.938	NS
	T1-T2	I-II	-0.167	0.599	NS
		II-III	-0.067	0.921	NS
		III-I	0.233	0.368	NS
	T2-T3	I-II	0.117	0.769	NS
		II-III	0.25	0.303	NS
		III-I	-0.367	0.079	NS

When the inter-brush evaluation was done between all three brushes for change in the mean of OPI score before brushing at the start of the study, i.e., T0, and mean of before brushing OPI score at the end of the study, i.e., T3, no significant difference was seen between any of the brushes (Table 7).

Table 7: Inter-Brush Comparison of reduction in mean OPI score before brushing over 6 weeks i.e., from T0 (Before) to T3 (Before)

		Mean Difference	Std. Error	p-Value	Significance
Brush I	Brush II	0.05	0.17055	0.954	NS
	Brush III	0.25	0.17055	0.31	NS
Brush II	Brush I	-0.05	0.17055	0.954	NS
	Brush III	0.2	0.17055	0.471	NS
Brush III	Brush I	-0.25	0.17055	0.31	NS
	Brush II	-0.2	0.17055	0.471	NS

Discussion

This research investigated whether a newly developed activated charcoal toothbrush could be more effective at removing plaque buildup in patients undergoing orthodontic treatment. The current study used two established indexes: the orthodontic plaque index and the gingival index. As more plaque-accumulating areas are formed due to the presence of orthodontic brackets and wire and elastomeric materials attached to teeth, maintaining oral hygiene becomes cumbersome for orthodontic patients when compared with non-orthodontic patients. In orthodontic patients, approaching such plaque-accumulating areas with the brushes becomes difficult. Therefore, having a specialized optimal brush for effectively cleaning areas becomes crucial in maintaining oral hygiene, ultimately improving orthodontic treatment and preventing cross-infection among oral practitioners. [10]

In this study, three types of brush designs were compared, i.e., activated charcoal brush having a V-cut design (Brush I), conventional orthodontic brush (Brush II) and activated charcoal brush having flat cut design (Brush III) for the effectiveness in reducing the plaque load in orthodontic patients. For the purpose of evaluating the oral health and plaque load in orthodontic patients, the GI [11], EIBI [12], and OPI [13] were used. The evaluation was done at every 2 weeks of interval and analysed by using paired T test and Tukey post-hock test.

To reduce the patient-induced bias, crossing over of brush type was done among the three sample groups of patients every six weeks, having a washout period of one week in between every cross-over to eliminate the effect

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of previously used toothbrushes. That implies all the patients made to use all the brushes with respect to the phase of the study so that effect of compliance to brushing method of individual can be nullified. Data collected from all the patients using a particular toothbrush throughout the study phases was combined and analysed. On intragroup comparison, it was seen that patients using Charcoal activated V-cut toothbrush throughout the study had a significant improvement in the gingival index improving their gingival health. While the ones using conventional orthodontic toothbrush had nonsignificant change in the gingival index which is opposed by Rafe et al [(14)], Rothbarth et al [(15)] and Gomes et al [(16)] where an improvement was reported in gingival index which differed from current study in respect to sample size and method of toothbrushing used and subjected to Hawthorne effect ("*situation in where people change their behavior because of the awareness of being observed in a study or experiment. It's essentially a reactivity to being watched*") [(17)]. For the patients using charcoal activated flat cut toothbrush had a significant increase of gingival index which differs from the study done by Kini et al [(18)] where they concluded decrease in gingival index. This can be justified by the difference in sample type of the study done by Kini et al [(18)] which included non-orthodontic patients. When bleeding index was compared in current study no significant effect was observed using any of the brushes. This finding is supported by Kiliçoğlu et al [(19)] and Rafe et al [(14)], using bleeding index as a variable for the assessment of oral health. This finding can be explained by the constant trauma or force level due to orthodontic appliance at a particular area. When intergroup comparison was done no significant difference was observed among the three brushes. This OPI reduction efficiency before and after brushing was assessed, patients using charcoal infused v-cut toothbrush had a significant decrease in OPI score reduction efficiency from before to after the brushing at subsequent intervals. This can be supported by the fact that it had reduced more plaque initially and throughout the study hinting at the improved performance, whereas patients using conventional orthodontic toothbrush and charcoal infused flat cut toothbrush had non-significant change in OPI score reduction efficiency.

Conclusion

Intragroup observation showed that the charcoal-activated v-cut toothbrush significantly reduced plaque and improved gingival health over six weeks of observation. More reduction was seen in the initial phases, showing its effectiveness in controlling orthodontic patients' oral hygiene. The conventional orthodontic toothbrush significantly reduced plaque and improved gingival health over six weeks of observation, showing its effectiveness in controlling oral hygiene in orthodontic patients. The charcoal-activated flat-cut toothbrush significantly reduced plaque and improved gingival health over six weeks of observation, showing its effectiveness in controlling oral hygiene in orthodontic patients. The charcoal-activated V-cut toothbrush showed the highest efficiency in plaque reduction, followed by conventional orthodontic toothbrushes and charcoal-activated flat-cut toothbrushes in orthodontic patients. However, no significant difference between the three was found.

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