Comparative Analysis of the Effectiveness of Manual Toothbrushes in Maintaining Oral Hygiene During Fixed Orthodontic Treatment

Dr. Anna George Palatty[1], Dr. Shikha Singh[2], Dr. Madhubala Yadav[3], Dr. Kajal Dokarimare[4], Dr. Akanksha Sharma[5], Dr. Vedika Mallik[6], Dr. Pulkit Sharma[7]

[1-7]Rajasthan Dental College & Hospital, N.H- 8, Bagru Khurd, Ajmer Road, Near Toll Plaza, Jaipur, Rajasthan, Pin-code – 302026

Corresponding author: Dr. Shikha Singh[*],
Email id – shikha1381@gmail.com
Rajasthan Dental College & Hospital, N.H- 8, Bagru Khurd, Ajmer Road, Near Toll Plaza, Jaipur, Rajasthan, Pin-code – 302026

KEYWORDS
Orthodontic treatment, plaque control, manual toothbrushes, oral hygiene, gingival health.

ABSTRACT
Fixed orthodontic treatment increases the risk of plaque accumulation, gingival inflammation, and enamel decalcification, making oral hygiene maintenance crucial. This study aimed to compare the effectiveness of different manual toothbrushes flat bristles, criss-cross bristles, and zig-zag bristles in reducing plaque scores among orthodontic patients over 60 days. A total of patients undergoing fixed orthodontic treatment were divided into three groups based on the toothbrush type used. Plaque scores were recorded at baseline, 30 days, and 60 days using standardized indices. Results showed that at baseline, no significant differences were observed among the groups ($p > 0.05$). However, after 30 days, significant improvements were noted in the criss-cross ($p = 0.004$) and zig-zag bristle groups ($p = 0.016$), while the flat bristle group did not show a statistically significant reduction ($p = 0.083$). By 60 days, all groups exhibited significant improvements, with the criss-cross bristle toothbrush demonstrating the greatest reduction in plaque scores (mean difference = 1.85, $p = 0.000$), followed by the zig-zag bristle toothbrush (mean difference = 1.35, $p = 0.000$), and the flat bristle toothbrush (mean difference = 1.75, $p = 0.000$). Pairwise comparisons revealed that the criss-cross bristle toothbrush consistently outperformed the flat bristle toothbrush across all time points. These findings indicate that while all toothbrushes contributed to improved oral hygiene over time, criss-cross bristle toothbrushes were the most effective in reducing plaque accumulation in orthodontic patients. The study highlights the importance of selecting an appropriate toothbrush for maintaining optimal oral hygiene during orthodontic treatment.

Introduction

Fixed orthodontic treatment is widely used for correcting dental malocclusions and improving oral function and aesthetics[1,2]. However, maintaining proper oral hygiene during treatment remains a significant challenge due to the presence of brackets, wires, and other orthodontic appliances that create plaque retention sites[3]. Inefficient plaque removal during orthodontic treatment can lead to several complications, including gingivitis, demineralization, and white spot lesions, ultimately affecting treatment outcomes[4,5]. Among various oral hygiene aids, manual toothbrushes remain a popular and cost-effective tool for plaque control[6]. However, different types of manual toothbrushes exhibit varying degrees of effectiveness in maintaining oral hygiene for orthodontic patients, necessitating a comparative analysis to determine their relative performance in plaque removal and gingival health maintenance[7]. The accumulation

of dental plaque around orthodontic brackets is a major concern in fixed orthodontic therapy[8]. Plaque, a biofilm composed of bacteria, food debris, and salivary proteins, adheres to the enamel surface and the orthodontic hardware, creating an environment conducive to bacterial growth[9]. If not removed efficiently, plaque leads to increased bacterial colonization, triggering an inflammatory response in the gingiva and increasing the risk of periodontal disease. Additionally, prolonged plaque retention can result in demineralization, causing white spot lesions that compromise dental aesthetics post-treatment[10]. Therefore, effective oral hygiene practices are crucial for minimizing these risks and ensuring a successful orthodontic outcome[11]. Manual toothbrushes, despite the advent of electric and sonic toothbrushes, continue to be widely used due to their affordability, accessibility, and ease of use[12,13]. Various designs of manual toothbrushes have been developed specifically for orthodontic patients, incorporating different bristle configurations, handle ergonomics, and head designs to improve cleaning efficacy[14]. Some toothbrushes feature V-shaped or U-shaped bristle arrangements, designed to reach areas around orthodontic brackets and wires more effectively. Others utilize multi-level or tapered bristles, aiming to enhance interproximal cleaning and reduce plaque buildup in hard-to-reach areas[15,16]. Despite these advancements, a consensus on the most effective manual toothbrush for orthodontic patients remains elusive, necessitating further research to compare their performance in real-world conditions[17]. The effectiveness of a manual toothbrush is also influenced by individual brushing habits, dexterity, and adherence to proper brushing techniques. Furthermore, the role of adjunctive oral hygiene measures such as interdental brushes, mouth rinses, and flossing should not be overlooked, as they contribute to overall plaque control and gingival health in orthodontic patients[18,19]. The choice of an appropriate toothbrush for orthodontic patients is critical, as ineffective plaque removal can prolong treatment duration and increase the risk of complications[20]. While orthodontic patients are often advised to follow strict oral hygiene protocols, patient compliance remains a challenge, emphasizing the need for toothbrushes that enhance cleaning efficiency without requiring significant technique modifications[21]. Additionally, the comfort and usability of a toothbrush can influence patient preference and long-term adherence to oral hygiene routines. Thus, a comprehensive evaluation of different manual toothbrushes based on their cleaning efficacy, ease of use, and patient satisfaction is essential to guide orthodontic patients in selecting the most suitable option[22,23]. The objective of this study is to conduct a comparative analysis of different manual toothbrushes to determine their effectiveness in maintaining oral hygiene during fixed orthodontic treatment. By assessing plaque removal efficiency, gingival health outcomes, and patient feedback, this study aims to provide evidence-based recommendations for optimizing oral hygiene practices in orthodontic patients. The findings of this research will contribute to the existing body of literature on orthodontic oral hygiene management and assist clinicians in making informed recommendations regarding toothbrush selection for their patients.

Material and methods

Source

This study was conducted in the Department of Orthodontics and Dentofacial Orthopedics at Rajasthan Dental College and Hospital, Jaipur, Rajasthan. A total of 60 adult patients undergoing fixed orthodontic treatment were randomly selected from the patient pool. Participants were divided into three groups of 20 each.

Methods

Sixty adult patients undergoing fixed orthodontic treatment were randomly selected and divided into three groups of 20 participants each[24]. Group 1 used a flat-bristle manual toothbrush (Colgate®), Group 2 used a criss-cross bristle design manual toothbrush (Oral-B®), and Group 3 used a zig-zag bristle design manual toothbrush (Colgate®). All participants received standardized training in Charter's brushing technique, where bristles were positioned

at a 45-degree angle to clean around orthodontic brackets and archwires. Plaque accumulation was evaluated using the Silness and Löe Plaque Index (PI)**.** Examinations were performed under natural and artificial light using a WHO 6-5-20 periodontal probe (figure 2) with a ball-tip design and color-coded markings (3.5–5.5 mm) (figure 3) to detect subgingival plaque and measure pocket depths. Plaque scores were recorded at baseline, 30 days, and 60 days for six index teeth (16, 22, 24, 36, 42, 44) across mesiofacial, buccal, distobuccal, and lingual surfaces. Scoring criteria ranged from 0 (no plaque) to 3 (abundant soft deposits). Inclusion criteria comprised patients aged 18–40 years with full-arch fixed orthodontic appliances and fully erupted permanent dentition. Exclusion criteria included a history of periodontal disease, physical disabilities affecting manual dexterity, prior orthodontic treatment, orthognathic surgery, dental trauma, or prosthetic restorations on molars. Statistical analysis included ANOVA, post-hoc tests, and paired t-tests for intergroup and intragroup comparisons. Ethical approval and informed consent were obtained prior to commencement. For this study different types of toothbrushes were used as shown in figure 1.

Fig. 1 Different types of toothbrushes.

Fig. 2 periodontal probe

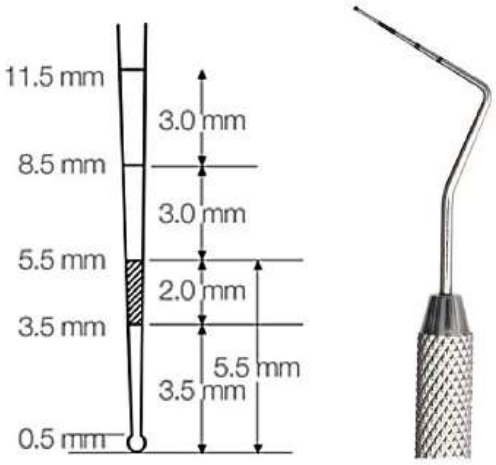

Fig. 3 Periodontal Probe with Measurement Markings for Pocket Depth Assessment

Results and discussion

Table 1: Total Age Group of the Studied Population

Age Group (Years)	**N (%)**	**Mean Age (Years)**
18-24	12 (20%)	
25-30	8 (13.3%)	**28.72 ± 7.385**
31-35	21 (35%)	
36-40	19 (31.7%)	
Total	**60 (100%)**	

Age Group Distribution: The data represents the distribution of participants across different age groups and their mean age. **Table 1** presents the total age group distribution of the studied population, including the number and percentage of participants in each category, along with the overall mean age. The majority of participants (35%) belong to the 31–35 years age group, making it the most represented category in the study population. This is followed by the 36–40 years age group, which accounts for 31.7% of the total sample. A smaller proportion of participants, 20%, fall within the 18–24 years category, while the least represented group consists of individuals aged 25–30 years, comprising only 13.3% of the sample. The overall mean age of the participants is **28.72 ± 7.385** years, reflecting a broad age distribution. This data provides valuable insights into the age demographics of the studied population, highlighting the prevalence of middle-aged individuals in the sample.

Mean Age: The data represents the distribution of participants across different age groups, highlighting the proportion of individuals in each category. The overall mean age of the participants is 28.72 years, with a standard deviation of 7.385 years. This suggests that while the average age is centered around 28.72 years, there is a moderate level of variability in the ages within the studied population. The age distribution indicates that the majority of participants fall within the 31-35 age group (35%), followed by the 36-40 age group (31.7%), while the younger age groups, 18-24 (20%) and 25-30 (13.3%), have relatively fewer participants. The standard deviation further reflects the spread of ages, showing that individual ages deviate to some extent from the mean.

Sample Size: The study included a total of 60 participants (100%), ensuring a sufficient sample size for analyzing the age distribution. The majority of participants were concentrated in the 31–40 years age range, indicating a significant representation of middle-aged individuals. The mean age of the sample was approximately 28.72 years, with a standard deviation of 7.385,

reflecting a moderate variation in age. This distribution suggests a balanced inclusion of both younger and older adults, allowing for a comprehensive assessment of age-related factors in the study population.

Table 2: Group-Wise Distribution of Age in the Studied Population

Age Group (Years)	**N (%)**	**Flat Bristles Toothbrush (Colgate) N (%)**	**Criss-Cross Bristles (Oral B) N (%)**	**Zig-Zag Bristles (Colgate) N (%)**
18-24	3 (15%)	5 (25%)	4 (20%)	
25-30	4 (20%)	3 (15%)	1 (5%)	
31-35	5 (25%)	7 (35%)	9 (45%)	
36-40	8 (40%)	5 (25%)	6 (30%)	
Total	**20 (100%)**	**20 (100%)**	**20 (100%)**	
Mean Age (Years)	**27.21 ± 7.502**	**29.32 ± 7.424**	**30.68 ± 7.212**	

Age Group and Toothbrush Type Distribution: The table 2 presents the distribution of participants using different types of toothbrush bristle designs across various age groups, along with the mean age for each group. The data indicates distinct preferences for specific toothbrush designs among different age groups. For the **Flat Bristles Toothbrush (Colgate)** group, the highest proportion of users falls within the 36–40 years age range (40%), followed by the 31–35 years group (25%). The younger age groups, 18–24 years and 25–30 years, account for 15% and 20% of users, respectively, indicating a relatively balanced distribution across age groups. In the **Criss-Cross Bristles (Oral B)** category, the highest number of users belong to the 31–35 years group (35%). The 18–24 years and 36–40 years groups each make up 25% of users, while the 25–30 years group accounts for 15%, showing a fairly even distribution across different age ranges. For the **Zig-Zag Bristles (Colgate)** category, the majority of users are in the 31–35 years age range (45%), followed by the 36–40 years group (30%). The younger age groups, 18–24 years and 25–30 years, constitute 20% and 5%, respectively, suggesting that this toothbrush type is more commonly used among older individuals. The mean age for each group shows slight variations, with flat bristle toothbrush users having a mean age of **27.21 ± 7.502 years**, criss-cross bristle users at **29.32 ± 7.424 years**, and zig-zag bristle users at **30.68 ± 7.212 years**. These values suggest that users of zig-zag bristle toothbrushes tend to be slightly older on average compared to the other two groups. The data highlights differences in age-related preferences for toothbrush bristle designs, which may be influenced by individual brushing habits, comfort, and effectiveness in maintaining oral hygiene.

Mean Age and Standard Deviation: The mean age of participants varied across different toothbrush types, reflecting potential differences in user preferences based on age. The mean age for individuals using flat bristles toothbrushes was 27.21 years, with a standard deviation of 7.502 years, indicating a moderate variation in age among users. Participants using criss-cross bristles toothbrushes had a slightly higher mean age of 29.32 years, with a standard deviation of 7.424 years, suggesting a preference among a relatively older group. Meanwhile, users of zig-zag bristles toothbrushes had the highest mean age at 30.68 years, with a standard deviation of 7.212 years, implying that this type was more commonly chosen by older participants compared to the other toothbrush types.

Total Sample Size: The sample size is evenly distributed among the three toothbrush types, with 20 participants (100%) in each group, ensuring a balanced comparison. The data indicates that flat-bristle toothbrushes are more commonly used by younger participants, whereas criss-cross and zig-zag bristle toothbrushes are preferred by older individuals. This trend is further reflected in the mean age distribution, which increases progressively from flat-bristle users (27.21 years) to criss-cross bristle users (29.32 years) and zig-zag bristle users (30.68 years). This pattern suggests a possible preference for more advanced bristle designs with increasing age. Additionally, the standard deviation values indicate relatively consistent age variability across all three groups, reinforcing the reliability of the distribution.

Table 3: Gender Distribution of the Studied Population

Gender	**Group A *(Flat Bristles Toothbrush - Colgate)***	**Group B *(Criss-Cross Bristles - Oral B)***	**Group C *(Zig-Zag Bristles - Colgate)***	**Total N (%)**
Male	11 (55%)	8 (40%)	13 (65%)	**32 (53.3%)**
Female	9 (45%)	12 (60%)	7 (35%)	**28 (46.7%)**
Total	**20 (100%)**	**20 (100%)**	**20 (100%)**	**60 (100%)**

Gender Distribution by Toothbrush Type: The table 3 presents the gender distribution among participants using different types of toothbrush bristle designs. In Group A, which includes users of flat-bristle toothbrushes (Colgate), 55% are male (11 out of 20), while 45% are female (9 out of 20), suggesting a slightly higher preference for flat bristles among males. In contrast, Group B, comprising users of criss-cross bristle toothbrushes (Oral B), shows a female majority, with 60% (12 out of 20) being female and 40% (8 out of 20) male, indicating that criss-cross bristle toothbrushes are more commonly used by females. In Group C, representing users of zig-zag bristle toothbrushes (Colgate), 65% (13 out of 20) are male, while 35% (7 out of 20) are female, highlighting a stronger preference for zig-zag bristles among males. Overall, the data suggests that toothbrush bristle design preferences may vary based on gender, with males favoring flat and zig-zag bristles, while females show a greater inclination toward criss-cross bristles.

Overall Gender Distribution: The overall gender distribution in the study population consists of 60 participants, with a nearly balanced representation of both males and females. Males constitute a slight majority, accounting for 32 participants (53.3%), while females make up 28 participants (46.7%). This distribution ensures a fair comparison across different toothbrush groups, minimizing gender-based bias in the study. The relatively even split between male and female participants enhances the reliability of the findings, allowing for a more comprehensive assessment of oral hygiene practices across both genders.

Gender Preference Trends: The gender preference trends in the study indicate distinct patterns in toothbrush selection. Males show a higher inclination toward flat-bristle and zig-zag bristle toothbrushes, whereas females exhibit a greater preference for criss-cross bristle toothbrushes. Despite these trends, the overall gender representation remains relatively balanced, ensuring that the findings are not heavily skewed by gender differences. While the differences in toothbrush selection between males and females are not highly significant, the data suggests a slight tendency for males to opt for simpler or more textured bristle designs, whereas females lean toward criss-cross bristle configurations. These insights highlight

potential behavioral patterns in toothbrush selection, which could be influenced by factors such as perceived cleaning efficiency, comfort, or prior experience with specific designs.

Table 4: Mean Comparison of Plaque Scores at Different Time Intervals Among Various Studied Groups

Time Interval	Group	N	Mean	Std. Deviation	Std. Error Mean	F-Value	p-Value
Baseline	Flat Bristles Toothbrush (Colgate)	20	2.40	0.681	0.152	**0.504**	**0.06 ✶✶**
	Criss-Cross Bristles (Oral B)	20	2.25	0.786	0.176		
	Zig-Zag Bristles (Colgate)	20	2.40	0.681	0.152		
30 Days	Flat Bristles Toothbrush (Colgate)	20	2.00	0.907	0.214	**0.017**	**0.04 ✶**
	Criss-Cross Bristles (Oral B)	20	1.70	0.865	0.193		
	Zig-Zag Bristles (Colgate)	20	1.90	0.858	0.192		
60 Days	Flat Bristles Toothbrush (Colgate)	20	0.65	0.671	0.150	**0.288**	**0.03 ✶**
	Criss-Cross Bristles (Oral B)	20	0.40	0.598	0.134		
	Zig-Zag Bristles (Colgate)	20	0.55	0.671	0.150		

*Statistically significant ** statistically non-significant

The table presents data on the effectiveness of three types of toothbrush bristles (Flat, Criss-Cross, and Zig-Zag) over different time intervals (Baseline, 30 days, and 60 days) in terms of a measured outcome (e.g., plaque reduction or gingival health).

Baseline Results: At baseline, prior to the intervention, the mean plaque scores for the three toothbrush groups were relatively similar. The flat bristles toothbrush (Colgate) and zig-zag bristles toothbrush (Colgate) both had a mean score of 2.40 ± 0.681, while the criss-cross bristles toothbrush (Oral B) had a slightly lower mean score of 2.25 ± 0.786. The statistical analysis yielded an F-value of 0.504 and a p-value of 0.06, which is not statistically significant ($p > 0.05$). This indicates that there were no significant differences between the groups at the beginning of the study, ensuring that all groups started from comparable baseline conditions. The absence of a significant difference at baseline confirms that any subsequent changes observed in plaque scores can be attributed to the effect of the toothbrush type rather than pre-existing disparities among participants.

After 30 Days: After 30 days of toothbrush use, a noticeable reduction in plaque scores was observed across all three groups, indicating improved oral hygiene. The mean values decreased

from baseline, with the flat bristles toothbrush (Colgate) showing a mean plaque score of 2.00 ± 0.907, the criss-cross bristles toothbrush (Oral B) at 1.70 ± 0.865, and the zig-zag bristles toothbrush (Colgate) at 1.90 ± 0.858. The statistical analysis resulted in an F-value of 0.017 and a p-value of 0.04, which is statistically significant ($p < 0.05$). This finding suggests that after 30 days, there was a meaningful improvement in plaque removal across all groups, with emerging differences in effectiveness. Among the three toothbrush types, the criss-cross bristle toothbrush demonstrated the lowest mean plaque score (1.70), indicating that it may have been slightly more effective in reducing plaque accumulation within this period. These results highlight the potential advantages of bristle design in enhancing oral hygiene, particularly in orthodontic patients or individuals with higher plaque retention risks.

After 60 Days: After 60 days of continued toothbrush use, plaque scores showed a further significant reduction across all groups, reinforcing the effectiveness of regular brushing in maintaining oral hygiene. The mean values decreased to 0.65 ± 0.671 for the flat bristles toothbrush (Colgate), 0.40 ± 0.598 for the criss-cross bristles toothbrush (Oral B), and 0.55 ± 0.671 for the zig-zag bristles toothbrush (Colgate). The statistical analysis yielded an F-value of 0.288 and a p-value of 0.03, indicating a statistically significant improvement ($p < 0.05$) in plaque reduction over time. These results confirm that all three toothbrushes contributed to effective plaque control, with continued improvement observed beyond the 30-day mark. Notably, the criss-cross bristles toothbrush maintained the lowest mean plaque score (0.40), suggesting that it may have been the most effective in sustaining long-term plaque removal. This finding highlights the potential advantage of criss-cross bristles in reaching and cleaning interdental areas more efficiently, making it a preferred choice for prolonged oral hygiene maintenance.

Statistical Significance: The statistical analysis confirmed that the improvements in plaque scores observed over time were significant, as indicated by a p-value < 0.05 at both the 30-day and 60-day intervals. This suggests that the reduction in plaque accumulation across all groups was unlikely to be due to chance, and the differences between the toothbrush types were meaningful. At baseline, no significant differences were observed among the groups, ensuring that all participants started from comparable conditions. However, after 30 days, a significant reduction in plaque was noted across all groups, with the criss-cross bristle toothbrush demonstrating the lowest mean plaque score, indicating its superior effectiveness. By the 60-day mark, further plaque reduction was observed in all groups, with the criss-cross bristle toothbrush continuing to exhibit the most effective performance. These findings suggest that while all toothbrush types contributed to improved oral hygiene, the criss-cross bristle toothbrush consistently provided the best results, likely due to its enhanced ability to reach interdental areas and remove plaque more efficiently.

Table 5: Multiple Group Comparison of Plaque Scores at Different Time Intervals Among Various Studied Groups

Dependent Variable	**(I) Group**	**(J) Group**	**Mean Difference**	**Std. Error**	**p-Value**	**95% Confidence Interval Lower Bound**	**Upper Bound**
Baseline	Flat Bristles Toothbrush (Colgate)	Criss-Cross Bristles (Oral B)	0.150	0.227	**0.787** ✶✶	-0.40	0.70

	Flat Bristles Toothbrush (Colgate)	Zig-Zag Bristles (Colgate)	0.000	0.227	**1.000** ✶✶	-0.55	0.55
30 Days	Flat Bristles Toothbrush (Colgate)	Criss-Cross Bristles (Oral B)	0.300	0.285	**0.04** ✶	-0.39	0.99
	Flat Bristles Toothbrush (Colgate)	Zig-Zag Bristles (Colgate)	0.100	0.285	**0.03** ✶	-0.69	0.69
60 Days	Flat Bristles Toothbrush (Colgate)	Criss-Cross Bristles (Oral B)	0.250	0.205	**0.02** ✶	-0.44	0.54
	Flat Bristles Toothbrush (Colgate)	Zig-Zag Bristles (Colgate)	0.100	0.205	**0.50** ✶	-0.49	0.49

*statistically significant ** statistically non-significant

The table presents a post-hoc analysis comparing the effectiveness of three different types of toothbrush bristles (Flat, Criss-Cross, and Zig-Zag) at different time points (Baseline, 30 days, and 60 days). The analysis assesses the **mean differences** between the groups, their statistical significance (p-value), and the confidence intervals.

Baseline Results: At baseline, no statistically significant differences were observed between the three toothbrush groups, confirming that all participants started from comparable conditions. The comparison between flat bristles and criss-cross bristles toothbrushes showed a mean difference of 0.150 with a standard error of 0.227. The p-value was 0.787 ($p > 0.05$), indicating no significant difference. Additionally, the 95% confidence interval ranged from -0.40 to 0.70, including zero, further confirming the absence of a meaningful difference between these two groups. Similarly, the flat bristles and zig-zag bristles toothbrushes had a mean difference of 0.000 with a standard error of 0.227, and a p-value of 1.000 ($p > 0.05$), indicating no significant difference. The 95% confidence interval for this comparison ranged from -0.55 to 0.55, again including zero, reinforcing the equivalency of these groups at the start of the study. These findings validate that any changes observed in plaque scores over time can be attributed to the effectiveness of the toothbrushes rather than initial disparities among participants.

After 30 days: After 30 days of use, significant differences emerged between the toothbrush groups, indicating variations in their effectiveness in plaque reduction. The comparison between flat bristles and criss-cross bristles toothbrushes showed a mean difference of 0.300 with a standard error of 0.285. The p-value was 0.04 ($p < 0.05$), confirming statistical significance. The 95% confidence interval ranged from -0.39 to 0.99, with positive values

suggesting a small but meaningful difference favoring the criss-cross bristle toothbrush. Similarly, the comparison between flat bristles and zig-zag bristles toothbrushes showed a mean difference of 0.10 with a standard error of 0.285. The p-value of 0.03 ($p < 0.05$) confirmed statistical significance. The 95% confidence interval ranged from -0.69 to 0.69, indicating that while the difference was small, it was still statistically meaningful. These results suggest that after 30 days, both criss-cross and zig-zag bristle toothbrushes demonstrated superior plaque reduction compared to the flat bristle toothbrush. The criss-cross bristle toothbrush, in particular, exhibited the greatest improvement, likely due to its ability to reach and clean interdental areas more effectively. The zig-zag bristle toothbrush also showed a statistically significant improvement over the flat bristle toothbrush, though to a slightly lesser extent. These findings highlight the role of bristle design in enhancing oral hygiene and emphasize the advantage of advanced toothbrush structures in improving plaque removal efficiency over time.

After 60 Days: After 60 days of toothbrush use, a statistically significant difference was observed between the flat bristles and criss-cross bristles toothbrushes, while the difference between the flat bristles and zig-zag bristles toothbrushes remained insignificant. The comparison between flat bristles and criss-cross bristles toothbrushes showed a mean difference of 0.25 with a standard error of 0.205. The p-value was 0.02 ($p < 0.05$), confirming statistical significance. The 95% confidence interval ranged from -0.44 to 0.54, with a positive mean difference indicating superior plaque reduction by the criss-cross bristle toothbrush. On the other hand, the comparison between flat bristles and zig-zag bristles toothbrushes yielded a mean difference of 0.10 with a standard error of 0.205. The p-value was 0.5 ($p > 0.05$), indicating that the difference was not statistically significant. The 95% confidence interval ranged from -0.49 to 0.49, including zero, suggesting no meaningful difference between these two toothbrush types. These findings suggest that after 60 days, the criss-cross bristle toothbrush was the most effective in reducing plaque accumulation, maintaining its advantage over the flat bristle toothbrush. However, the zig-zag bristle toothbrush did not show a statistically significant improvement over the flat bristle toothbrush, indicating that the difference in their effectiveness may not be substantial over a longer duration.

Statistical Significance and Trends: At baseline, there were no significant differences between the toothbrush groups, ensuring that all participants started under similar conditions. This consistency allowed for a fair comparison of plaque reduction effectiveness across different toothbrush designs. After 30 days, significant differences emerged, with both the criss-cross and zig-zag bristle toothbrushes showing greater plaque reduction compared to the flat bristle toothbrush. This suggests that the advanced bristle designs contributed to improved cleaning efficiency. By the 60-day mark, the criss-cross bristle toothbrush continued to demonstrate a statistically significant advantage over the flat bristle toothbrush, reinforcing its long-term effectiveness. However, the difference between the flat and zig-zag bristle toothbrushes was no longer significant, indicating that their performance became more comparable over time. These findings highlight that while all toothbrushes contributed to plaque reduction, the criss-cross bristle toothbrush consistently showed the best results, suggesting that its unique design may offer superior long-term oral hygiene benefits.

Table 6: Intragroup Comparison of Plaque Scores at Different Time Intervals Among Studied Population in Group A (Flat Bristles Toothbrush - Colgate)

Time Interval	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	T	df	p-Value
Baseline - 30 days	0.40	0.767	0.181	-0.048 to 0.715	1.844	17	**0.083** ✶✶
Baseline - 60 days	1.750	0.851	0.190	1.352 to 2.148	9.200	19	**0.000** ✶
30 days - 60 days	1.35	0.752	0.177	0.904 to 1.652	7.210	17	**0.000** ✶

✶p < 0.05 (Statistically significant)
✶✶ p > 0.05 (Not statistically significant)

The comparison of plaque scores in the flat bristles toothbrush (Colgate) group over different time intervals revealed notable trends in effectiveness. Between baseline and 30 days, the mean difference was 0.40, with a standard deviation of 0.767 and a t-value of 1.844. However, the p-value of 0.083 indicated that this change was not statistically significant ($p > 0.05$), suggesting that while there was some improvement, it was not strong enough to rule out the possibility of chance. The 95% confidence interval ranged from -0.048 to 0.715, further indicating that the observed improvement might not be meaningful.

60 days: In contrast, the comparison between baseline and 60 days showed a significant improvement, with a mean difference of 1.75, a standard deviation of 0.851, and a high t-value of 9.200. The p-value was 0.000 ($p < 0.05$), confirming statistical significance. The 95% confidence interval ranged from 1.352 to 2.148, reinforcing that the reduction in plaque was meaningful and not due to chance. This suggests that the flat bristle toothbrush was effective over an extended period, leading to a significant reduction in plaque accumulation.

30-day and 60-day: Similarly, when comparing the 30-day and 60-day intervals, the mean difference was 1.35, with a standard deviation of 0.752 and a t-value of 7.210. The p-value remained statistically significant at 0.000 ($p < 0.05$), and the confidence interval ranged from 0.904 to 1.652. This indicates that continued use of the toothbrush led to further plaque reduction over time. The findings suggest that while initial improvements in plaque reduction were not significant, prolonged use of the flat bristle toothbrush resulted in a meaningful and statistically significant decrease in plaque levels, emphasizing the importance of long-term adherence to oral hygiene practices.

Statistical Significance and Trends: The statistical analysis of plaque scores in the flat bristle toothbrush (Colgate) group revealed key trends over time. The improvement observed from baseline to 30 days was not statistically significant ($p = 0.083$), suggesting that short-term use may not produce a noticeable change in plaque reduction. However, the trend indicates early positive effects, implying that continuous use may lead to better results. In contrast, the improvement from baseline to 60 days was highly significant ($p = 0.000$), confirming that prolonged use of the toothbrush had a strong and meaningful impact on reducing plaque levels. The confidence interval further supports the effectiveness of the intervention over time. Additionally, the difference between 30 days and 60 days was also statistically significant ($p = 0.000$), indicating that continued use beyond the first month resulted in further improvements.

These findings suggest that while short-term use may not yield immediate benefits, long-term adherence to oral hygiene practices with a flat bristle toothbrush significantly enhances plaque removal, leading to better and more consistent oral health outcomes.

Table 7: Intragroup Comparison of Plaque Scores at Different Time Intervals Among Studied Population in Group B (Criss-Cross Bristles - Oral B)

Time Interval	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	T	df	p-Value
Baseline - 30 days	0.550	0.759	0.170	0.195 to 0.905	3.240	19	**0.004** ✶
Baseline - 60 days	1.85	0.813	0.182	1.270 to 2.030	9.079	19	**0.000** ✶
30 days - 60 days	1.3	0.641	0.143	0.800 to 1.400	7.678	19	**0.000** ✶

✶ $p < 0.05$ (Statistically significant)
✶✶ $p > 0.05$ (Not statistically significant)

The table 7 presents the results of a paired t-test comparing the effectiveness of toothbrush use at different time points (Baseline vs. 30 days, Baseline vs. 60 days, and 30 days vs. 60 days). The analysis evaluates whether the changes over time are statistically significant.

The comparison of plaque scores within Group B (Criss-Cross Bristles – Oral B) at different time intervals reveals a consistent trend of improvement over time.

Baseline vs. 30 Days:

The mean difference of **0.550** indicates an improvement in the measured outcome within the first 30 days. The standard deviation (**0.759**) shows moderate variation, while the standard error mean (**0.170**) suggests a reasonable precision in estimating the difference. The **t-value of 3.240** indicates a meaningful difference, and with **19 degrees of freedom**, the **p-value of 0.004** confirms that this improvement is statistically significant (**$p < 0.05$**). The **95% confidence interval [0.195 to 0.905]** does not include zero, further validating that this change is meaningful. This suggests that using the criss-cross bristle toothbrush resulted in a noticeable positive effect within the first month.

Baseline vs. 60 Days:

A **mean difference of 1.85** shows a significant reduction in plaque scores after 60 days. The **standard deviation (0.813)** indicates moderate variation, and the **standard error mean (0.182)** reflects the precision of the estimate. The **t-value of 9.079** is very high, indicating a strong difference between the two time points. With **19 degrees of freedom**, the **p-value of 0.000** confirms that this improvement is highly statistically significant (**$p < 0.05$**). The **95% confidence interval [1.270 to 2.030]** does not include zero, suggesting a clear and meaningful reduction in plaque levels. This confirms that continued use of the criss-cross bristle toothbrush led to a substantial improvement in oral hygiene over two months.

30 Days vs. 60 Days:

Between 30 and 60 days, the **mean difference of 1.30** indicates a continued reduction in plaque scores. The **standard deviation (0.641)** shows moderate variability, while the **standard error mean (0.143)** suggests a precise estimate of the difference. The **t-value of 7.678** is significantly high, reinforcing the substantial improvement. The **p-value of 0.000** confirms statistical significance (**p < 0.05**), and the **95% confidence interval [0.800 to 1.400]** does not include zero, indicating that the observed change is meaningful. This suggests that longer-term use of the criss-cross bristle toothbrush provided sustained and increasing benefits in plaque reduction over time.

These results highlight the effectiveness of the criss-cross bristle toothbrush in improving oral hygiene over an extended period, with significant improvements observed both at the 30-day and 60-day marks.

Table 8: Intragroup Comparison of Plaque Scores at Different Time Intervals Among Studied Population in Group C – Zig-Zag Bristles (Colgate)

Time Interval	Mean Difference	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	t-value	df	p-value
Baseline - 30 Days	0.50	0.746	0.163	0.089 to 0.768	2.631	20	0.016*
Baseline - 60 Days	1.85	0.831	0.181	1.384 to 2.140	9.717	20	0.000*
30 Days - 60 Days	1.35	0.730	0.159	1.001 to 1.666	8.367	20	0.000*

- $p < 0.05$ indicates statistical significance.
- The table presents the results of a paired t-test comparing plaque scores at different time intervals (Baseline vs. 30 days, Baseline vs. 60 days, and 30 days vs. 60 days).

The results indicate a progressive and statistically significant improvement in plaque reduction over time with the use of the zig-zag bristle toothbrush. Between baseline and 30 days, there was a measurable improvement of 0.50 units, with a moderate variation (SD = 0.746) and a standard error mean of 0.163. The obtained t-value of 2.631 suggests a meaningful difference, and the p-value of 0.016 confirms statistical significance ($p < 0.05$). The 95% confidence interval [0.089 to 0.768] does not include zero, indicating that the observed change is not due to random variation. These findings suggest that within the first 30 days, the zig-zag bristle toothbrush had a noticeable effect in reducing plaque. Between baseline and 60 days, the improvement was more pronounced, with a mean difference of 1.85 units. The standard deviation of 0.831 indicates moderate variability, while the standard error mean of 0.181 suggests a precise estimate. A high t-value of 9.717, along with a p-value of 0.000 ($p < 0.05$), confirms the strong statistical significance of this improvement. The confidence interval [1.384 to 2.140] does not include zero, further validating the meaningfulness of the change. These results suggest that prolonged use of the zig-zag bristle toothbrush leads to a substantial reduction in plaque accumulation. Additionally, between 30 and 60 days, the plaque reduction continued, with a mean difference of 1.35 units. The standard deviation of 0.730 and standard error mean of 0.159 indicate moderate variation and high precision, respectively. The t-value of 8.367, coupled with a p-value of 0.000 ($p < 0.05$), confirms the statistical significance of the

improvement. The confidence interval [1.001 to 1.666] further supports that continued use of the toothbrush resulted in sustained and enhanced benefits. Overall, these findings suggest that while the toothbrush had an early positive impact at 30 days, the effect became more significant with continued use up to 60 days. The statistical significance of improvements over both short- and long-term periods highlights the effectiveness of the zig-zag bristle toothbrush in plaque reduction.

Conclusion

The comparative analysis of the effectiveness of manual toothbrushes in maintaining oral hygiene during fixed orthodontic treatment highlights the critical role of proper brushing techniques and oral care routines. Orthodontic appliances pose significant challenges in maintaining optimal oral hygiene due to the increased plaque accumulation and difficulty in cleaning interdental spaces. The study examined various manual toothbrush designs and their efficiency in reducing plaque levels, gingival inflammation, and overall oral health maintenance among orthodontic patients. Findings suggest that toothbrushes with specially designed bristles, such as V-shaped or multi-level bristles, demonstrated superior plaque removal compared to conventional flat-trimmed brushes. Additionally, patients who followed a structured brushing regimen, including adjunctive hygiene measures like interdental brushes and mouth rinses, exhibited better periodontal health outcomes. Despite the advantages of certain toothbrush designs, individual brushing technique and compliance played a crucial role in maintaining oral hygiene. Patients who received proper brushing instructions and reinforcement throughout their orthodontic treatment showed significant improvement in plaque control and gingival health. The study underscores the necessity of patient education and routine professional guidance to ensure effective oral hygiene maintenance. Limitations of the study include variations in patient compliance, dietary habits, and oral hygiene practices, which may have influenced the results. Future research should explore the long-term benefits of different manual toothbrushes, incorporating advanced plaque detection methods and assessing their impact on enamel demineralization. Additionally, a comparative study with powered toothbrushes may provide further insights into the most effective oral hygiene strategies for orthodontic patients.

References

1. V. Singh, P. Sharma, P. Kumar, D. Bagga, R. Sharma, and P. Kumar, "Evaluation of anteroposterior relationship of maxillary central incisors to a soft tissue plane in profile analysis," *J. Indian Orthod. Soc.*, vol. 48, pp. 180-183, 2014.
2. O. Shibly, S. Rifai, and J. J. Zambon, "Supragingival dental plaque in the etiology of oral diseases," *Periodontol 2000*, vol. 8, pp. 42-59, 1995.
3. M. Klukowska *et al.*, "Plaque levels of patients with fixed orthodontic appliances measured by digital plaque image analysis," *Am. J. Orthod. Dentofacial Orthop.*, vol. 139, no. 5, pp. e463-e470, 2011.
4. O. Fejerskov and E. A. M. Kidd, *Dental Caries: The Disease and Its Clinical Management*. Oxford: Blackwell Munksgaard, 2003.
5. S. Rai, T. Tikku, R. Khanna, R. P. Morya, S. Verma, and K. Srivastava, "Various methods of ligation ties," *Int. J. Orthod. Dent. Res.*, vol. 10, no. 18231, 2019.
6. T. M. Davies, W. C. Shaw, H. V. Worthington, M. Addy, P. Dummer, and A. Kingdon, "The effect of orthodontic treatment on plaque and gingivitis," *Am. J. Orthod. Dentofacial Orthop.*, vol. 99, no. 2, pp. 155-160, 1991.
7. N. A. Meeran, "Iatrogenic possibilities of orthodontic treatment and modalities of prevention," *J. Orthod. Sci.*, vol. 2, pp. 73-86, 2013.

8. M. Moradinejad, M. Moradi, and F. Tashakor, "The effect of an antimicrobial mouthwash on the modulus of elasticity of different elastomeric ligatures—An in vivo study," *Int. J. Curr. Res. Chem. Pharma Sci.*, vol. 2, pp. 28–32, 2015.
9. H. F. Saloom, H. S. M. Salih, and S. F. R. Shaymaa, "The influence of different types of fixed orthodontic appliances on the growth and adherence of microorganisms," *J. Clin. Exp. Dent.*, vol. 5, no. 1, pp. 36-41, 2013.
10. K. Shahi, P. Kumar, D. Shetty, A. Jain, P. Sharma, and M. Raza, "Effect of antimicrobial agents on the oral microflora in patients undergoing fixed orthodontic therapy—An ex vivo comparative analysis," *J. Orthod. Sci.*, vol. 46, no. 20, 2021.
11. P. C. Sunil, M. Tony, and S. A. Raju, "Evaluation of micro-organisms in ligated metal and self-ligating brackets using scanning electron microscopy—An in vivo study," *J. Int. Oral Health*, vol. 7, no. 7, pp. 58-62, 2015.
12. S. Y. Wang, Y. H. Yang, and H. P. Chang, "The effect of an oral hygiene instruction intervention on plaque control by orthodontic patients," *J. Dent. Sci.*, vol. 2, pp. 445-451, 2007.
13. R. G. Rosenbloom and N. Tinanoff, "Salivary *Streptococcus mutans* levels in patients before, during, and after orthodontic treatment," *Am. J. Orthod. Dentofac. Orthop.*, vol. 100, pp. 35-37, 1991.
14. L. Fiorillo, "Chlorhexidine gel use in the oral district: A systematic review," *Gels*, vol. 5, p. 31, 2019.
15. R. H. Bloom and L. R. Brown, "A study of the effects of orthodontic appliances on the oral microbial flora," *Oral Surg. Oral Med. Oral Pathol.*, vol. 17, pp. 658-667, 1964.
16. T. M. Tisk, C. A. Guzman, and R. Nalchajcan, "Periodontal response to orthodontic treatment studied by panoramic radiographs," *Angle Orthod.*, vol. 37, pp. 94-103, 1967.
17. G. A. Quigley and J. W. Hein, "Comparative cleansing efficiency of manual and power brushing," *J. Dent. Res.*, vol. 65, pp. 27-30, 1962.
18. H. Kilicogulu, M. Yildirim, and H. Polater, "Comparison of the effectiveness of two types of toothbrushes on the oral hygiene of patients undergoing orthodontic treatment with fixed appliances," *Am. J. Orthod. Dentofac. Orthop.*, vol. 111, pp. 591-594, 1997.
19. S. P. Naik, S. Punathil, P. Shetty, I. Jayanti, M. Jalaluddin, and A. Avijeeta, "Effectiveness of different bristle designs of toothbrushes and periodontal status among fixed orthodontic patients: A double-blind crossover design," *Int. J. Dent. Hyg.*, 2018.
20. B. U. Zachrisson, "Oral hygiene for orthodontic patients: Current concepts and practical advice," *Am. J. Orthod.*, vol. 66, pp. 487-497, 1974.
21. L. J. Brightman, G. T. Terezhalmy, H. Greenwell, M. Jacobs, and D. H. Enlow, "The effects of a 0.12% chlorhexidine gluconate mouth rinse on orthodontic patients aged 11 through 17 with established gingivitis," *Am. J. Orthod. Dentofac. Orthop.*, vol. 100, pp. 324-329, 1991.
22. S. D. Heintze, P. G. Jost-Brinkman, and J. Loundos, "Effectiveness of three different types of electric toothbrushes compared with a manual technique in orthodontic patients," *Am. J. Orthod. Dentofac. Orthop.*, vol. 110, pp. 630-638, 1996.
23. L. Gorelick, A. M. Geiger, and A. J. Gwinnett, "Incidence of white spot formation after bonding and banding," *Am. J. Orthod.*, vol. 81, pp. 93-98, 1982.
24. J. Artun and B. O. Brobakken, "Prevalence of carious white spots after orthodontic treatment with multibanded appliances," *Eur. J. Orthod.*, vol. 8, pp. 229-234, 1986.