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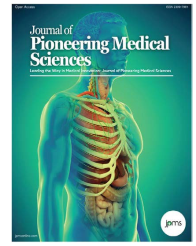

Effect of a Sound-Guided Toothbrush on Cervical Abrasion Progression in Fixed Partial Denture Abutments: A Randomized Controlled Clinical Trial

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Abstract **Background:** Cervical abrasion is a common non-carious cervical lesion, particularly in patients with Fixed Partial Dentures (FPDs), where abutment teeth are exposed to increased mechanical stress during tooth brushing. Toothbrush design and brushing technique significantly influence lesion progression. **Aim:** To compare the progression of cervical abrasion in FPD abutment teeth using a sound-guided novel toothbrush versus a conventional manual toothbrush. **Materials and Methods:** Eighty adults requiring FPDs and presenting with mild pre-existing cervical abrasion (Smith and Knight score 1-2) were randomly allocated into two groups: Group A (conventional toothbrush) and Group B (sound-guided novel toothbrush). Participants brushed twice daily for six months. Cervical abrasion was assessed at baseline and follow-up using the Smith and Knight index. Intra- and inter-group comparisons were performed using paired and independent t-tests. **Results:** Both groups exhibited progression of cervical abrasion over six months. Group A demonstrated a mean increase of 0.6±0.2, whereas Group B showed a smaller increase of 0.2±0.1. The difference in progression between groups was statistically significant ($p<0.05$). **Conclusion:** Cervical abrasion progressed in both groups; however, progression was significantly lower among users of the sound-guided toothbrush. Auditory feedback may assist in modifying brushing movements and reducing mechanical stress at the cervical region. Larger and longer-term studies are required to confirm these findings.

Key Words Cervical Abrasion, Fixed Partial Denture, Sound-Guided Toothbrush, Non-Carious Cervical Lesion, Smith and Knight Index

INTRODUCTION

Cervical abrasion represents a common manifestation of Non-Carious Cervical Lesions (NCCLs), involving the progressive loss of dental hard tissue at or near the cementoenamel junction (CEJ). This lesion is primarily associated with mechanical factors, particularly improper tooth brushing techniques, which over time can compromise the structural integrity of the cervical region. Understanding the influence of different brushing methods and tools is therefore critical to establishing evidence-based preventive strategies and minimizing the risk of dental tissue loss.

Dentin Hypersensitivity (DH) is frequently encountered in clinical dental practice and poses significant challenges for both patients and clinicians. It predominantly affects individuals aged between 20 and 50 years [1]. The widely recognized hydrodynamic theory explains the pathophysiology of DH by describing fluid movement within exposed dentinal tubules in response to thermal, mechanical, chemical or osmotic stimuli. These fluid shifts stimulate nerve endings within the pulp, resulting in acute, short-lived pain. Accurate diagnosis of DH necessitates a combination of visual examination and standardized stimuli, such as tactile probing or controlled air blasts [1].

Anatomical and histological features of the cervical region, including thinner enamel and proximity to the CEJ, render this area particularly susceptible to structural damage. Cervical abrasion often initially presents as a shallow, horizontal groove located on the buccal or labial surfaces of teeth. These lesions are typically smooth and polished and tactile examination often elicits sensitivity [2].

Mechanically induced cervical lesions are pathologically driven by repeated exposure to forces such as aggressive brushing, abrasive dentifrices or foreign objects habitually applied near the teeth. Alongside attrition and erosion, cervical abrasion is categorized under NCCLs and is commonly associated with discomfort, hypersensitivity, or, in severe cases, pulpal involvement [3]. The development of cervical abrasion is multifactorial, with forceful brushing, high-abrasive toothpaste and to a lesser extent, chemical erosion and occlusal stress (abfraction) contributing to the condition [3].

Although the lesion evolves gradually, it triggers natural defensive responses in dental tissues, including the deposition of secondary and tertiary dentin or sclerotic dentin. If left unmanaged, cervical abrasion can exacerbate plaque accumulation, intensify tooth sensitivity, provoke pulpal inflammation and compromise periodontal health. Management strategies therefore focus on symptom alleviation, restoration of lost tooth structure and mitigation of associated soft tissue complications [4].

The progression of cervical abrasion is influenced by a combination of biological, chemical and behavioral factors. Cementum and dentin are particularly vulnerable, often resulting in wedge- shaped or V-shaped defects accompanied by gingival recession [5]. Mechanical tooth brushing habits-especially those involving excessive force or the use of abrasive toothpastes-are established as principal contributors to cervical abrasion. The condition is more prevalent in incisors, canines and premolars than in molars [6].

Despite being a fundamental aspect of personal oral hygiene, improper tooth brushing can inadvertently contribute to cervical tissue loss. Overzealous brushing, the use of hard-bristled toothbrushes and application of highly abrasive toothpaste have been consistently implicated as risk factors. While cervical abrasion can affect individuals across all age groups, modifiable behaviors-particularly brushing techniques-remain the most significant determinants of lesion development. Studies examining optimal brushing frequency, duration and technique have yielded variable findings, indicating the need for more precise, evidence-based guidelines. The influence of chemical factors, including dietary acids and toothpaste abrasivity, also warrants further investigation.

Distinguishing cervical abrasion from other NCCLs-such as erosion and abfraction-remains a notable clinical challenge. Abrasion arises primarily from mechanical forces, whereas erosion results from acid-mediated demineralization and abfraction is linked to occlusal stress-induced microfractures. This overlap complicates the isolation of specific causative factors, emphasizing the importance of comprehensive research into brushing habits and lesion development [7].

Brushing force is a major factor in lesion formation. While gentle brushing with soft-bristled brushes is generally recommended, debates continue regarding their comparative effectiveness against harder bristles. Similarly, the choice between manual and powered toothbrushes remains contentious. Some studies suggest that pressure-sensitive powered brushes reduce cervical tissue damage, whereas others caution that oscillatory motion may exert additional stress on dental structures.

Brushing technique itself is a critical determinant of cervical abrasion risk. Methods such as Bass, Stillman and Fones vary in bristle angulation, motion and applied force. Their impact on cervical abrasion, particularly in patients with exposed roots or gingival recession, requires further exploration. Additionally, the interplay between brushing frequency, duration and applied force underscores the complex nature of lesion development, highlighting the need for patient-centered preventive strategies tailored to individual oral health profiles.

In recent years, innovation in toothbrush design has focused on balancing mechanical cleaning efficacy with tissue preservation. Novel toothbrushes incorporating natural antimicrobial agents, such as neem-based filaments, have demonstrated potential in reducing oral bacterial load while minimizing abrasive damage to cervical regions. Such advancements reflect an ongoing effort to integrate oral health promotion with sustainable dental care solutions, which may prove especially valuable for populations at elevated risk of cervical abrasion.

Taken together, cervical abrasion represents a multifactorial dental concern with significant clinical implications. Comprehensive understanding of brushing techniques, brush design and patient behavior is essential to prevent lesion progression, manage dentin hypersensitivity and optimize long-term dental health. The present study aims to comparatively evaluate the effect of a novel toothbrush versus conventional toothbrushes on cervical abrasion in fixed partial denture abutments, contributing valuable insights to evidence-based oral hygiene recommendations.

Cervical abrasion is a form of Non-Carious Cervical Lesion (NCCL) characterized by the gradual loss of tooth structure at or near the cementoenamel junction due to mechanical factors. Among these, tooth brushing habits-including force, direction and brush design-are considered the primary contributors. In patients rehabilitated with Fixed Partial Dentures (FPDs), abutment teeth may be particularly susceptible due to altered plaque retention patterns, gingival recession and increased exposure of root surfaces.

Improper brushing techniques, especially horizontal scrubbing movements, are strongly associated with increased cervical wear. Over time, such abrasion can compromise dentin integrity, contribute to dentin hypersensitivity and predispose abutment teeth to restorative and periodontal complications. Therefore, strategies that assist patients in maintaining appropriate brushing movements may play a role in limiting lesion progression.

Recent advances in toothbrush design have attempted to incorporate feedback mechanisms to guide brushing behavior. Sound-guided toothbrushes provide auditory cues based on brushing direction, encouraging vertical or circular strokes while discouraging horizontal movements associated with cervical abrasion. Despite increasing interest in behavior-guided oral hygiene devices, clinical evidence evaluating their impact on cervical abrasion-particularly in high-risk populations such as FPD patients-remains limited.

Existing studies largely focus on powered toothbrushes or pressure-sensitive devices, with minimal attention given to low-cost mechanical feedback systems such as sound guidance. Furthermore, few clinical trials have specifically assessed abrasion progression in FPD abutment teeth, which represent a clinically relevant yet under-investigated population.

Therefore, the present randomized controlled clinical trial aimed to evaluate and compare the progression of cervical abrasion in FPD abutments using a sound-guided novel toothbrush versus a conventional manual toothbrush over a six-month period.

Objectives

Primary Objective

- To compare the progression of cervical abrasion in FPD abutment teeth between users of a sound-guided toothbrush and a conventional manual toothbrush over six months

Secondary Objective

- To assess whether auditory feedback influences brushing movement patterns associated with cervical abrasion progression

MATERIALS AND METHODS

The Patent Granted tooth brush for teaching proper brushing technique, includes a head containing of plurality of bristles, neck portion, shank and elongated handle body, characterized in that shank comprises a cavity, where in the said cavity a detachable body contains a plurality of grooves inside, where in said grooves beads are contained such that a beat sound is produced when the brush strokes are in circular or angulated up and down motion and when the brush strokes are in translational to and fro or horizontal motion, the beats engage in the grooves and no beat sound is produced (Figure 1).

Figure 1: The Patent Granted Tooth Brush

Study Design

A randomized, controlled, single-blind clinical trial conducted over six months in the Department of Prosthodontics, [Institution Name].

Ethical Approval

Approved by the Institutional Ethics Committee (Reference No: IHEC/SDC/PHD/PROSTHO-2426/25/TH-007). Written informed consent was obtained from all participants.

Study Population

Inclusion Criteria

- Adults aged 20-60 years
- Patients requiring fixed partial dentures
- Presence of mild cervical abrasion (Smith and Knight score 1-2) on abutment teeth
- Good periodontal health

Exclusion Criteria

- Parafunctional habits (bruxism, nail biting)
- Systemic diseases affecting oral health
- Use of highly abrasive dentifrices
- Restored or fractured abutment teeth

Sample Size and Randomization

Eighty participants were randomly allocated into two groups (n = 40 each) using computer-generated randomization.

- **Group A:** Conventional soft-bristled manual toothbrush
- **Group B:** Sound-guided manual toothbrush providing auditory feedback during brushing movements

Description of the Sound-Guided Toothbrush

The novel toothbrush incorporates a mechanical auditory feedback mechanism within the shank. When vertical or circular brushing movements are performed, beads within internal grooves produce a distinct sound. Horizontal brushing movements do not generate sound, thereby providing immediate feedback and encouraging recommended brushing directions.

Clinical Procedure

Participants received standardized oral hygiene instructions and were instructed to brush twice daily using their assigned toothbrush and fluoridated toothpaste. No additional brushing aids were permitted.

Cervical abrasion was recorded at baseline and six months using the Smith and Knight index by a single examiner blinded to group allocation.

Statistical Analysis

Data were analyzed using SPSS version 25. Paired t-tests assessed intra-group changes and independent t-tests evaluated inter-group differences. Statistical significance was set at $p<0.05$.

Results (Aligned & Consistent)

All 80 participants completed the six-month follow-up. Baseline demographic characteristics and abrasion scores were comparable between groups (p>0.05).

Both groups showed a statistically significant increase in abrasion scores over time. Group A demonstrated greater progression compared to Group B. Inter-group analysis revealed a significantly lower mean increase in abrasion scores in the sound-guided toothbrush group (p<0.05).

Statistical Analysis

Data were entered into SPSS v.25. Descriptive statistics were computed and intra-group comparisons were analyzed using paired t-tests, while inter-group comparisons were assessed using independent t-tests. A p-value <0.05 was considered statistically significant.

RESULTS

A total of 80 participants (40 in each group) successfully completed the 6-month follow-up period, with no dropouts reported. At baseline, both groups were comparable in terms of demographic and clinical variables, including age distribution, gender ratio, baseline abrasion scores and type of FPD. No statistically significant differences were observed between the groups at the start of the study (p>0.05), confirming group homogeneity (Table 1).

Within-group comparisons revealed a progression in cervical abrasion scores from baseline to follow-up in both groups. In Group A (conventional toothbrush), the mean abrasion score increased from 1.4±0.3 at baseline to 2.0±0.4 at follow-up, with a mean change of 0.6±0.2 (p<0.001). In Group B (novel toothbrush), the mean scores increased from 1.3±0.2 at baseline to 1.5±0.2 at follow-up, with a mean change of 0.2±0.1 (p<0.01). These intra-group results are summarized in Table 2.

Between-group analysis confirmed that the increase in abrasion scores was significantly greater in Group A compared to Group B, with a mean difference in change of 0.4 (p<0.05) (Table 3).

In addition to the tabulated data, graphical representations (Figure 2-4) provide a clearer visualization of the study findings. Figure 2 shows that the highest prevalence of cervical abrasion occurred in the 26-35 years age group, followed by younger adults aged 18-25 years, with a gradual decline in older participants. Figure 3 highlights the key outcome of this study: The novel toothbrush produced markedly lower mean abrasion scores compared to the regular toothbrush, emphasizing its effectiveness in minimizing cervical abrasion. These visual comparisons strengthen the evidence presented in the tables and enhance the interpretability of the results.

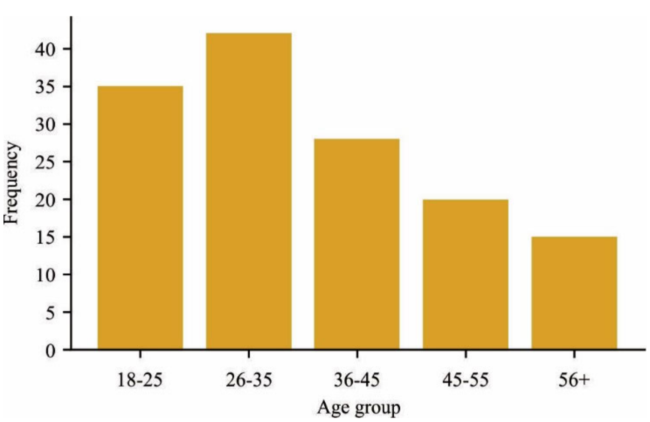

Figure 2: Age-Wise Distribution of Cervical Abrasion Among Study Participants

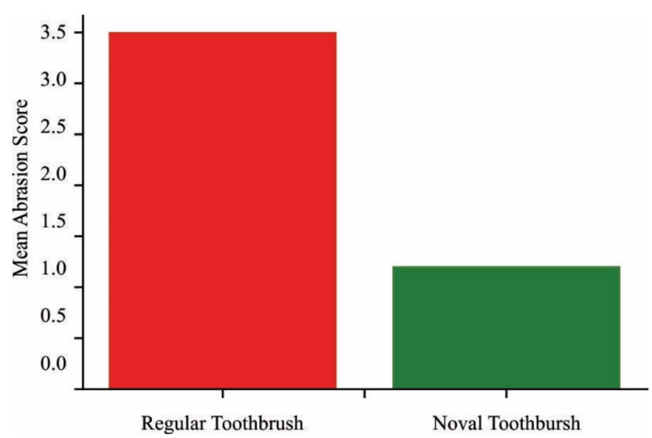

Figure 3: Comparison of Mean Cervical Abrasion Scores Between Regular and Novel Toothbrush Groups

Table 1: Baseline Characteristics of Study Groups

Variable	Group A (Conventional Toothbrush)	Group B (Novel Toothbrush)	p-value
Age (years, Mean±SD)	35.2±6.1	34.8±5.9	>0.05
Gender (M/F)	22/18	21/19	>0.05
Baseline abrasion score (Mean±SD)	1.4±0.3	1.3±0.2	>0.05
Type of FPD (anterior/posterior)	28-Dec	14/26	>0.05

Table 2: Within-Group Comparison of Abrasion Scores

Group	Baseline (Mean±SD)	Follow-up (Mean±SD)	Mean Change	p-value
Group A (Conventional Toothbrush)	1.4±0.3	2.0±0.4	0.6±0.2	<0.001
Group B (Novel Toothbrush)	1.3±0.2	1.5±0.2	0.2±0.1	<0.01

Figure 4(a-b): (a) Conventional Toothbrush Users and (b) Novel Toothbrush Users

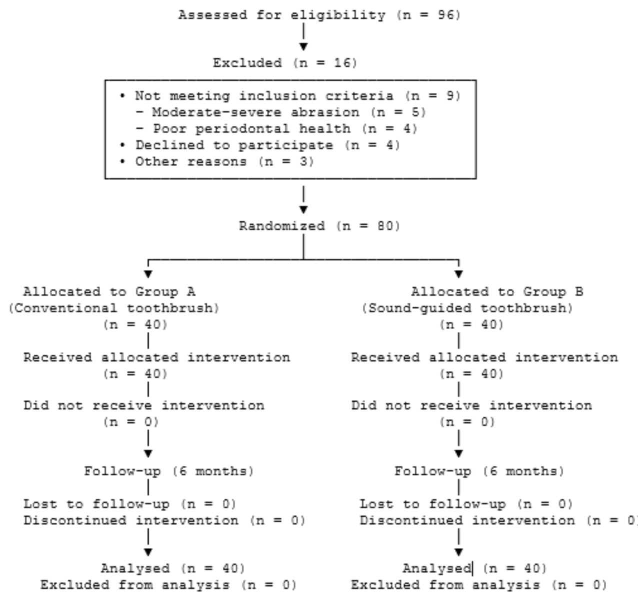

Figure 5: CONSORT Flow Chart

Table 3: Between-Group Comparison of Abrasion Progression

Comparison	Value	p-value
Mean difference in change (Group A-Group B)	0.4	<0.05

Overall, the findings indicate that although cervical abrasion progressed in both groups, the degree of progression was substantially lower in patients using the novel toothbrush. The built-in sound indicator and directional bristle design appeared to promote better compliance with vertical brushing, reducing mechanical stress at the cervical margin (Figure 4).

DISCUSSION

This study evaluated the progression of cervical abrasion in FPD abutment teeth using a sound-guided toothbrush compared to a conventional manual toothbrush. The findings indicate that while cervical abrasion progressed in both groups over six months, the degree of progression was significantly lower among users of the sound-guided toothbrush.

The observed difference may be attributed to the auditory feedback mechanism, which likely discouraged horizontal brushing movements known to exert greater mechanical stress at the cervical margin. Previous studies have consistently associated horizontal scrubbing with increased cervical wear, particularly in teeth with exposed root surfaces.

FPD abutment teeth represent a clinically relevant population due to altered biomechanics and plaque retention. By focusing on this group, the present study contributes evidence specific to prosthodontic patients, an area that remains under-represented in abrasion research.

Unlike powered or pressure-sensitive toothbrushes, the sound-guided device evaluated in this study offers a simple mechanical feedback system without reliance on electronics. This may have implications for cost-effectiveness and accessibility, particularly in resource-limited settings.

However, the study has limitations. Examiner calibration was not formally assessed, compliance could not be objectively monitored and the follow-up period was relatively short. Additionally, the presence of pre-existing abrasion limits interpretation to progression rather than prevention.

Non-Carious Cervical Lesions (NCCLs) constitute a prevalent category of dental wear and are frequently observed across diverse populations. These lesions encompass abrasion, abfraction and erosion, each with distinct etiologies. Abrasion results from mechanical forces unrelated to normal physiological functions such as mastication, with improper use of toothbrushes and abrasive dentifrices being the most common contributors. Such forces typically produce wedge-shaped defects on exposed root surfaces [3,4]. Abfraction arises from flexural stresses generated by occlusal loading, while erosion is characterized by chemical dissolution of enamel and dentin in the absence of bacterial activity [4].

Cervical abrasion specifically stems from repetitive mechanical contact with the tooth surface. Aggressive brushing techniques, use of hard-bristled toothbrushes and highly abrasive toothpastes have been consistently implicated in its pathogenesis [7]. The presence of erosive agents-such as dietary acids-can further compromise the cervical region, predisposing teeth to mechanical wear [8].

A major challenge in the diagnosis and management of cervical abrasion is the absence of standardized clinical assessment tools. Although several classification systems exist-such as those proposed by Eccles, Smith and Knight and Lussi-their variability limits the comparability of findings across studies. Recently, the Cervical Abrasion Index of Treatment Needs (CAITN) probe has been introduced to provide standardized lesion depth measurements and facilitate treatment planning [1]. Adoption of such tools is crucial for advancing research and improving clinical decision-making.

The prevalence of cervical abrasion is influenced by both demographic and behavioral factors. Older individuals are more frequently affected and there is a well-documented association with brushing behaviors, particularly force, technique and bristle hardness [4]. While no consistent gender differences have been reported, lesions are often observed in posterior and maxillary teeth [3]. The use of standardized indices such as CAITN can enhance data uniformity, allowing for more accurate epidemiological assessments and evidence-based recommendations [2].

Management of cervical abrasion aims to arrest lesion progression, alleviate dentin hypersensitivity, prevent pulpal involvement and restore esthetics [9-11]. Patient education is a cornerstone of preventive care, encompassing appropriate brushing force, brush selection and toothpaste choice [12]. In cases necessitating restorative intervention, Resin-Modified Glass Ionomer Cements (RMGICs) and composite resins are frequently employed. RMGICs, in particular, have demonstrated superior retention in some clinical scenarios, offering advantages for the long-term management of cervical lesions [13,14].

Tooth brushing behaviors play a pivotal role in cervical abrasion development. Horizontal brushing, especially when performed with excessive force, is strongly associated with increased tooth surface loss at the cervical margin [15]. Conversely, the modified Bass technique, which incorporates angled, gentle, vibratory strokes, is less likely to induce trauma and is considered protective [16,17]. Electric toothbrushes with integrated pressure sensors represent a promising tool for mitigating abrasion, particularly for patients with aggressive brushing habits or limited manual dexterity [18]. Brushing frequency and duration also significantly influence lesion risk, with sessions exceeding two minutes or performed more than twice daily contributing to cumulative mechanical stress [15]. Encouraging gentle brushing for approximately two minutes remains a key preventive measure [19].

Studies evaluating cervical abrasion exhibit variability in methodology, follow-up periods and sample sizes, which constrains the generalizability of findings. Standardization of diagnostic criteria, uniform use of indices such as CAITN and extended follow-up durations are recommended to enhance the quality of evidence. Future research should also focus on the synergistic effects of toothpaste abrasivity, brushing techniques and toothbrush types [20,21].

Innovative toothbrush designs integrating natural antimicrobial components have shown potential benefits. For instance, a toothbrush manufactured with neem fiber, neem powder and PLA filaments demonstrated antibacterial activity while maintaining enamel integrity. Functional group analysis, crystalline structure evaluation and morphological assessment indicated the presence of cellulose, carbohydrates and nimbin-compounds with known oral health benefits. The high amorphous content (89%) suggests reduced crystallinity, which may enhance antibacterial efficacy. Such eco-friendly designs represent a convergence of modern dental care and sustainable oral health strategies [22].

Toothbrush education remains essential, particularly for children and caregivers. Brushing twice daily under parental supervision is recommended and awareness of brush type, bristle diameter (soft: 0.2 mm; medium: 0.3 mm; hard: 0.4 mm) and appropriate force is critical for preventing abrasion [22,26]. Historical techniques, such as the Fones method (1913), are primarily advised for younger children, whereas the Bass and Modified Bass techniques are suitable for adolescents and adults. The Stillman and Charter methods provide alternative approaches, with variations in bristle angulation and motion to optimize plaque removal and minimize trauma [23].

The use of ultrasonic toothbrushes has been shown to reduce oral and salivary bacterial counts compared to conventional brushing, highlighting their potential utility in specialized populations. Nonetheless, proper guidance is necessary to ensure effective use [24]. Moreover, toothbrushes used by individuals with gingivitis may harbor higher levels of bacterial contamination, including Staphylococcus aureus and Streptococcus mutans, emphasizing the importance of hygiene, storage and timely replacement [25].

Electric toothbrushes may be less effective for visually impaired individuals due to limited tactile feedback and reliance on visual cues such as timers and pressure sensors. In such cases, caregivers and healthcare providers play a critical role in facilitating effective oral hygiene through adaptive tools, manual brushing and tailored instructions [26].

Finally, numerous factors influence the surface roughness and wear of teeth, including brushing technique, duration, frequency, bristle diameter and shape, applied force, brush direction and maintenance. Awareness and modification of these factors are essential for preventing cervical abrasion and maintaining long-term dental health [27].

In conclusion, cervical abrasion is a multifactorial condition primarily driven by mechanical tooth brushing behaviors, modulated by toothbrush type, bristle hardness and patient habits. Preventive strategies should emphasize patient education, appropriate brushing techniques and the use of innovative toothbrush designs. Standardized assessment tools, such as CAITN, along with longitudinal research, are essential to further elucidate lesion etiology and optimize management. The present study aims to assess the comparative efficacy of a novel toothbrush versus conventional toothbrushes in preventing cervical abrasion in fixed partial denture abutments, providing evidence for best practices in oral hygiene.

Full-mouth rehabilitation patients are particularly vulnerable to recurrent caries, with Streptococcus mutans levels and high cariogram scores identified as significant risk factors [28]. Long-term follow-up demonstrates that these interventions achieve high clinical success while substantially improving oral health-related quality of life over time [29]. Proper brushing technique, especially manual brushing, has been shown to effectively reduce plaque accumulation and cervical abrasion, emphasizing skill over the type of toothbrush [30]. Rapid improvements in child and family well-being are observed even within weeks after treatment, highlighting the immediate impact of comprehensive rehabilitation [31]. Early identification of dental fear using validated scales like Oddbods allows for targeted interventions to support cooperative behavior [32]. Preappointment parental counseling further alleviates anxiety in both children and parents, promoting adherence to oral hygiene recommendations [33]. Sensory-adaptive dental environments significantly improve behavior and comfort during procedures, creating a supportive setting for ongoing oral care [34].

Improper horizontal brushing with excessive force has been significantly associated with increased cervical abrasion, particularly affecting mandibular premolars, highlighting the importance of force control [35]. Simulated studies demonstrate that To-Fro brushing produces greater surface roughness compared to oscillatory techniques, indicating the protective advantage of controlled motion [36]. Similarly, horizontal strokes have shown significantly higher surface abrasion than vertical brushing methods [37]. Reinforcement of structured oral hygiene practices has been associated with improved long-term oral health outcomes [38]. Supportive non-invasive approaches that reduce discomfort during dental care may improve patient acceptance and cooperation [39]. Structural alterations in enamel composition can predispose teeth to mechanical wear under repetitive brushing forces [40]. The use of topical fluoride varnish strengthens enamel and forms an essential component of preventive protocols [41]. Standardized professional education remains crucial to ensure proper implementation of preventive strategies [42]. Advances in nanotechnology offer antimicrobial benefits that may aid in plaque control around abutment margins [43]. Behavioral management strategies such as conscious sedation can enhance cooperation and compliance with oral hygiene instructions [44]. Furthermore, bioactive materials and green-synthesized silver nanoparticles demonstrate promising antibacterial and biocompatible properties, potentially supporting peri-abutment health and limiting abrasion progression [45,46].

Integrating preventive strategies, behavioral management and environmental adaptations is therefore essential to maintain oral health post-rehabilitation. Overall, a multifaceted approach combining clinical, behavioral and educational interventions is critical to minimizing cervical abrasion and ensuring long-term success in these patients.

CONCLUSIONS

Within the limitations of this study, cervical abrasion progressed in both groups over six months; however, progression was significantly lower among users of the sound-guided toothbrush. Auditory feedback may assist in modifying brushing movements and reducing cervical abrasion progression in FPD abutment teeth. Further long-term studies with rigorous methodological controls are required before clinical recommendations can be made.

Competing Interests

One of the authors is associated with the development of the sound-guided toothbrush evaluated in this study. This has been disclosed and no external commercial funding was received.

Future Scope

- Longitudinal studies with larger sample sizes and extended follow-up periods are needed to validate these findings
- Comparative studies evaluating different novel toothbrush designs, including powered brushes with pressure sensors, could provide deeper insights
- Future research should incorporate patient-reported outcomes, such as ease of use and comfort, alongside clinical measurements
- Integration of digital monitoring (smart toothbrush apps) could further improve compliance and precision in oral hygiene studies

Limitations

- Short follow-up duration
- Lack of objective compliance monitoring
- Absence of examiner reliability testing
- Findings limited to mildly abraded FPD abutments

Ethical Statement

The study protocol was reviewed and approved by the Institutional Ethical Committee Approval Certificate Reference Number-IHEC/SDC/PHD/PROSTHO-2426/25/TH-007.

Written informed consent to participate was obtained from all participants prior to enrollment in the study. For participants under 18 years of age, consent was obtained from a parent or legal guardian.

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