CLINICAL RESEARCH

A Clinical Comparative Evaluation of the Wear of Enamel Antagonists Against Monolithic Zirconia and Metal-Ceramic Crowns

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Purpose: To evaluate and compare the wear of natural enamel against metal-ceramic and monolithic zirconia crowns, with the null hypothesis that there would be no difference in wear between metal-ceramic and monolithic zirconia. ***Materials and Methods:*** In 30 subjects within the age range of 18 to 40 years, two bilaterally opposing molars (maxillary/mandibular) were prepared to receive a monolithic zirconia crown or a metal-ceramic crown with feldspathic porcelain veneer. A polyvinyl siloxane impression of the opposing arch was taken at the time of cementation and 1 year after cementation. Casts were poured in type III gypsum and scanned, and the images were superimposed onto each other. AutoCAD was used to calculate the difference between the two images, which corresponded to the linear wear of the antagonist teeth. Statistical analysis of the data was done using one-way analysis of variance (ANOVA) and post hoc Tukey honest significant difference test for intergroup comparison. The P value obtained by one-way ANOVA was $1.1102e^{-16}$ (< .05), and by post hoc Tukey test was .001. ***Results:*** The mean wear of enamel against enamel was 14.8 ± 1.3 μm; of enamel against metal-ceramic was 87.1 ± 18.3 μm; and of enamel against monolithic zirconia was 59.4 ± 13.6 μm. The P values obtained indicated that the difference in wear of the antagonist tooth between monolithic zirconia and metal-ceramic was significant. ***Conclusion:*** It can be concluded that monolithic zirconia causes less wear of antagonist teeth than metal-ceramic veneered with feldspathic porcelain. *Int J Prosthodont 2021;34:744–751. doi: 10.11607/ijp.6598*

Wear of tooth structure is a natural and inevitable process that occurs when tooth and tooth, or tooth and restoration, are in contact with and slide against each other. This process may be further accelerated by the introduction of restorations whose properties of wear differ from those of the tooth structure that they slide against. It has been shown that enamel may be subject to accelerated wear when opposed by ceramic[1]; hence, it is desirable that the wear behavior of restorative materials be similar to natural enamel because excessive wear could lead to clinical problems such as damage to the occlusal surfaces of teeth, loss of vertical dimension of occlusion, poor masticatory function associated with temporomandibular joint remodeling, dentin hypersensitivity, and, often, compromised esthetic properties.[2–4] Given the complexity of the masticatory system, bite force, which has long been considered a contributing factor to prosthesis wear and survival, has been a very important point of interest.

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From the advent of gold as a restorative material, many alloys and ceramics have been used for fixed partial denture fabrication. All of these materials exhibit different rates of wear on the opposing natural teeth. Porcelain is described as abrasive, brittle, technique sensitive to polishing, and wear resistant.[5] The more highly polished and glazed the surface, the less abrasive porcelain becomes, but it still remains abrasive unless opposing another porcelain surface.[5] A machined ceramic showed the least enamel wear and was also the most wear resistant among several types of porcelains evaluated.[5]

The process of antagonistic tooth wear appears to be closely related to ceramic microstructure, surface roughness, and oral environmental influences.[5] During the past decade, zirconia-based ceramics have been successfully used to fabricate fixed dental prostheses (FDPs), along with a dental CAD/CAM system. Yttria partially stabilized tetragonal zirconia polycrystal (Y-TZP) ceramics showed better mechanical properties and superior resistance to fracture than other conventional dental ceramics.[6] Along with superior resistance to wear, marginal adaptation of zirconia-based FDPs is also acceptable for clinical application.[6] The scientific literature shows that zirconia has proved to be a suitable substructure ceramic with a wide range of indications, including for large fixed partial dentures in stress-bearing regions.[7] Clinical studies also indicate that zirconia is a viable material for both anterior and posterior fixed partial prostheses with excellent short-term survival rates; however, it must be covered with glass-ceramic, as it is opaque white in color, which frequently chips off. Several proposals for overcoming the chipping problem have been published, and, as a result, advances in CAD/CAM technology and the techniques used for zirconia materials, such as CAD/CAM–fabricated nonveneered monolithic zirconia restorations, have become increasingly popular.[8] In vitro studies have been carried out to calculate the wear of natural enamel antagonists and show that monolithic zirconia causes less wear than feldspathic porcelain.[9–12]

Although these studies allow for precise control of the environment and other variables that influence the wear of dental hard tissues due to various biomaterials, there is little correlation between in vitro findings and clinical performance.[13] Due to the various complex mechanisms affecting the wear process in the oral cavity (bite force, cyclic loading, action of saliva, etc), a clinical study is needed.[13–15] To date, only a couple of in vivo studies have been conducted to assess the wear of enamel against various restorative materials.[14,16] The aim of the present study was therefore to evaluate and compare the wear of natural enamel against metal-ceramic and monolithic zirconia crowns, with the null hypothesis that there would be no significant difference in the wear of antagonist enamel against metal-ceramic crowns with feldspathic porcelain veneer vs a monolithic zirconia crown.

MATERIALS AND METHODS

This in vivo study involved a total of 30 subjects within the age range of 18 to 40 years (mean age: 29 years) requiring two crowns in the maxillary or mandibular arch in the posterior (first molar) region, selected following the inclusion/exclusion criteria. Ethical clearance was obtained from the institution's ethics committee (Reference no. GDCHM/PG/2015-16/TitleSynopsis/7699/2015). Informed written consent was obtained from every patient. All procedures were carried out by a single operator (P.D.) to rule out any interoperator bias.

The inclusion criteria were: good oral hygiene and periodontal status; teeth selected to receive crowns should be restorable, and the crown to root ratio at least 1:1; healthy opposing natural teeth; availability for follow-up; and a full complement of teeth (excluding third molars).

The exclusion criteria were: developmental defects of enamel and dentin; medically compromised patients (calcium or metabolic disorders, osteoporosis, etc); parafunctional habits (bruxism, clenching) and/or TMJ disorder; and opposite teeth having caries or attrition.

In each subject, the teeth/restorations were divided into two main groups:

- Group 1: Control group, natural enamel opposing natural teeth
- Group 2: Experimental group

The teeth/restorations in the experimental group were further categorized into two subgroups:

- Group 2a: Natural enamel opposing metal-ceramic crowns with feldspathic porcelain veneer
- Group 2b: Natural enamel opposing polished monolithic zirconia

The preliminary impressions of the maxillary and mandibular arches were made with irreversible hydrocolloid (Valplast), and casts were poured in type III gypsum (Kalabhai). Modeling wax (2 mm thick; Sigmadent) was applied over the cast (Fig 1), and custom trays were fabricated using light-curing acrylic sheets (Individo Lux, Voco; Fig 2). For every patient, one monolithic zirconia and one metal-ceramic crown were fabricated for each side. The tooth preparation guidelines for the monolithic zirconia crown were an axial reduction of 1.5 mm, occlusal reduction of 2 mm, and a radial shoulder finish line (0.8 to 1 mm) with an equigingival margin. For the metal-ceramic crown, the axial reduction was 1.5 mm, occlusal reduction was 2 mm, the buccal shoulder finish line was 1 mm, and the lingual chamfer finish line was 0.5 mm (Fig 3).

After tooth preparation, gingival retraction was done using 0.5 mg/in aluminum chloride pre-impregnated retraction cord (Medi-Pak). A layer of VPS tray adhesive (3M Espe) was applied to the tissue surface and borders

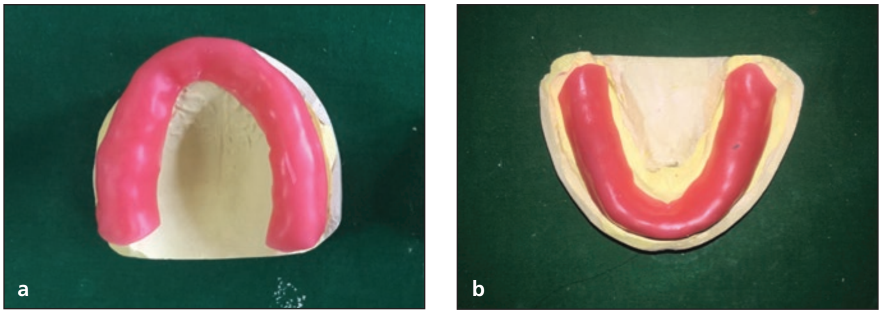

Fig 1 *(a)* Maxillary and *(b)* mandibular casts with modeling wax spacer.

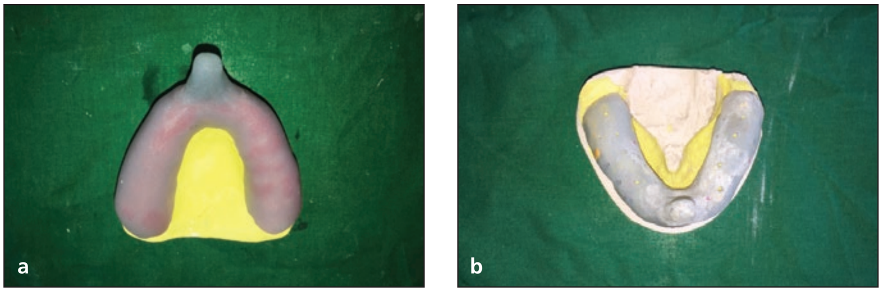

Fig 2 *(a)* Maxillary and *(b)* mandibular custom trays.

of the custom tray. The definitive impression was made using automix polyvinyl siloxane medium-body impression material (Aquasil, Dentsply Sirona) using a single-step technique (Fig 4). The impression was examined for any voids or defects in critical areas, and, if found satisfactory, the impression was used for the working cast fabrication, to be poured in type IV gypsum product (Kalabhai). Temporization was done with bisacryl composite material (Luxatemp, DMG) and cemented with zinc oxide–based noneugenol cement (Temp-Bond NE, Kerr Dental).

For metal-ceramic crowns, the working cast was prepared using type IV gypsum product, followed by die cutting and die ditching. The wax pattern was fabricated using PKT instruments. Investing and casting were done using the conventional lost-wax technique. This was followed by veneering of the metal coping for dentin and enamel buildup. A glaze mixture was applied on the crown, and final glazing was performed at 8,800°C.

Monolithic zirconia crowns (DC Monolith, DC-Zirkon) were fabricated using CAD/CAM technology (Wieland Dental). The working cast was obtained in type IV gypsum. Die cutting and ditching were performed, followed by application of titanium dioxide spray to dull the surfaces of the die. An extraoral optical scanner (Medit Identica) was used for scanning of the die. The design of the crown on the screen was done with the keyboard, mouse, and software support. The opposing cast was also scanned for the proper occlusal contacts in centric occlusion for designing the crown. The 3D shape was milled from a presintered zirconium dioxide (ZrO_2) blank (DC Zirkon) using hard metal tools. Glazing was done by applying a thin layer of glaze on the crown.

The crowns were cemented using glass-ionomer luting cement (GC Fuji I Luting and Lining Cement, GC; Fig 5). The patients were recalled after 24 hours and at 1 year postcementation for follow-up. An impression of the opposing arch was made 24 hours after cementation and at 1 year after cementation with medium-body polyvinyl siloxane (Aquasil) using a single-stage technique (Fig 6). Casts were poured in type IV gypsum (Kalabhai). The

Fig 3 Tooth preparation.

Fig 4 Final impression.

Fig 5 Cementation.

Fig 6 Impression of opposing arch.

casts were then scanned using a 3D white light scanner (SmartSCAN 3D-HE, Breuckmann). Acquisitions were taken along a 360-degree arc at variable angles, and alignment and merging were performed with proprietary software (OptoCat, Breuckmann). At 1 year after cementation, the patients were recalled, and an impression of the opposing arch was taken, followed by scanning of the casts. Baseline scan images were superimposed over each of the successive annual images (Fig 7).

The respective maxillary/mandibular first molars were scanned for measurement of wear of the tooth opposing the zirconia and metal-ceramic crowns, and the mandibular right and left second premolars were scanned using a 3D white light scanner (SmartSCAN 3D-HE) for measuring wear against natural enamel. The principle was based on the miniature projection technique (MPT), combining the Gray code and phase shift method. MPT uses two 1.4-MP RGB cameras and a fringe pattern projector to capture both geometry and texture for a measurable field of 90 mm with a manufacturer-specified measurement precision of 9 μm. The color scale was marked in microns for measurement of deviation. It was observed that there was a varying degree of occlusal wear seen on the occlusal surfaces of opposing teeth. On the color scale, light green and yellow colors represent a positive and a negative deviation, respectively, of 0 to 50 μm. Olive green and dark yellow represent a positive and a negative deviation, respectively, of 50 to 150 μm. For the purposes of standardization, the maximum wear readings on the corresponding points of both the antagonist occlusal surfaces were taken into consideration.

Finally, the wear amount (deviation in three axes) was calculated by software (PolyWorks, InnovMetric) in microns. Statistical software (SPSS version 20.0, IBM) was employed to carry out the statistical analysis of the data obtained. The parameters were observed to follow a normal distribution; hence, one-way repeated analysis of variance (ANOVA; $P < .05$) was used to measure significance of the means among the three groups. Post hoc Tukey test was performed to carry out intergroup comparisons ($P < .01$).

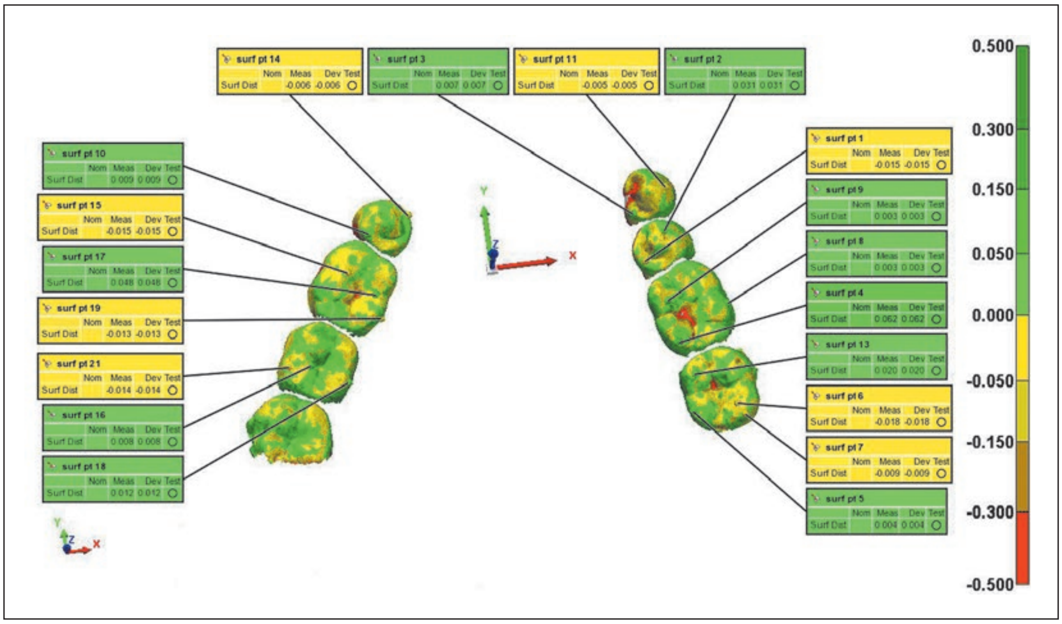

Fig 7 Superimposition of scans (mandibular).

RESULTS

The mean wear of enamel against enamel was 14.8 ± 1.3 µm; against metal-ceramic was 87.1 ± 18.3 µm; and against monolithic zirconia was 59.4 ± 13.6 µm.

The *P* value obtained by one-way ANOVA was $1.1102e^{-16}$ (< .05; Table 1). Results of the post hoc Tukey test are shown in Table 2.

The control group, in which natural enamel was opposed to natural enamel, demonstrated the least amount of wear after 1 year; this difference was statistically significant ($P = 1.1102e^{-16}$; < .05) compared to the experimental groups. Metal-ceramic crowns produced the greatest amount of wear on the opposing enamel, whereas the enamel wear opposing the zirconia crown was significantly less ($P < .05$) than against metal-ceramic after 1 year.

The *P* value obtained by the post hoc HSD Tukey test was .001, suggesting that the difference in wear between the various groups was highly significant.

DISCUSSION

The present study showed that the wear of the antagonist enamel against monolithic zirconia (59.4 ± 13.6 µm) was much lower than the wear of the antagonist enamel against metal-ceramic (87.1 ± 18.3 µm) after 1 year. Because monolithic zirconia was less harmful to the opposing dentition than metal-ceramic, the null hypothesis was rejected.

In selecting an appropriate restorative material, the wear behavior in the oral cavity should be considered. An ideal restorative material resembles the characteristics of natural enamel as closely as possible,[15,17] both in terms of adequate wear resistance and reduced abrasiveness. Lambrechts et al[18] reported that vertical wear of enamel is 20 to 40 µm a year under normal conditions. Therefore, it is important to evaluate the wear resistance of restorative materials against the opposing natural teeth and the physical properties of restorative materials. Dental porcelain was introduced approximately 100 years ago and has been used for more natural and esthetic restorations. The increased use of ceramics for restorative procedures and demand for improved clinical performance has led to the development and introduction of several new ceramic restorative materials and techniques. Y-TZP–based systems are a recent addition to the high-strength, all-ceramic systems used for crowns and fixed partial dentures. CAD/CAM–produced Y-TZP–based systems are in considerable demand in esthetic and stress-bearing regions.[6]

Wear in the oral cavity can be classified as two-bodied wear or three-bodied wear. Two-bodied wear is wear in the presence of saliva alone, whereas three-bodied wear

Table 1 Results of One-Way ANOVA

Groups	Group 1 (enamel/enamel)	Group 2a (enamel/PFM)	Group 2b (enamel/zirconia)
Mean ± SD	14.758 ± 1.299	87.100 ± 18.286	59.400 ± 13.599
F ratio	220.914	220.914	220.914
df	86	86	86
P	$1.1102e^{-16}$*	$1.1102e^{-16}$*	$1.1102e^{-16}$*

*Significant ($P < .05$). df = degrees of freedom.

Table 2 Results of Post Hoc Tukey Honest Significant Difference (HSD) Test

Intergroup comparison	Tukey HSD Q statistic	Tukey HSD *P*	Tukey HSD inference
Group 1 vs 2a	18.169	.001	$P < .01$*
Group 1 vs 2b	29.459	.001	$P < .01$*
Group 2a vs 2b	11.289	.001	$P < .01$*

*Significant.

is wear in the presence of other mediators besides saliva, such as food and paste.[10] This study investigated three-body abrasion because it simulates human mastication with abrasive foods, such as grain and bread. Wear is introduced when a surface is rubbed away by an "intervening slurry of abrasive particles." During mastication, abrasion is generated by the forceful sliding action of one tooth (first body) past another (second body), with the food bolus acting as the third body. At the same time, attrition occurs as a result of direct contact with the opposing teeth.[9]

There are several in vitro studies on the evaluation of wear of antagonist enamel against zirconia,[9,11,19–21] but only a couple of in vivo studies.[16,22–24] There is a need for further in vivo studies because the oral cavity is associated with different conditions, such as the abrasive influence of food, antagonistic contact during mastication, swallowing and occlusal movements, and biting forces in different directions with different magnitudes. Also, the complex wet environment of the oral cavity, which is impossible to produce in vitro, can impart positive surface charges on ceramic material, leading to a loss of sodium ions on the interacting aqueous environment and thereby reducing surface hardness. The microstructural components of different dental ceramics interact differently within the oral environment. This interaction may affect the behavior of the ceramics. Some in vitro studies have questioned the effect of hardness on wear, finding that relatively soft ceramics exhibited more abrasive action against human enamel than other ceramics.[25] The aim of this study was to evaluate and compare the wear of the natural tooth structure opposing metal-ceramic (with a feldspathic porcelain occlusal surface) and zirconia crowns. The measurements of wear were conducted from a clinical perspective. The scanning parameters, area to be scanned, scanning technique, and data analysis determined the accuracy and reproducibility of this technique.

With the technique employed in this study, not only the total wear amount, but also the wear of the specific area, was determined. The data collected were analyzed using IBM SPSS software, and $P < .05$ was considered statistically significant.

The results of the present study suggest that the mean wear of enamel opposing enamel was 14.8 ± 1.3 μm annually. The wear of enamel opposing metal-ceramic was 87.1 ± 18.3 μm annually, which was significantly higher than enamel vs enamel, and the wear of enamel opposing monolithic zirconia was significantly lower than that of metal-ceramic, at 59.4 ± 13.6 μm annually.

Zirconia has a strong surface hardness in comparison to other low-fusing feldspathic porcelains; therefore; more wear was expected from zirconia. However, Seghi et al,[25] Dahl and Oilo,[14] and Callister[26] agreed with evidence suggesting that the hardness of the restoration material alone is not a reliable predictor of the wear of enamel.

DeLong et al[27] reported that the relationship of wear to hardness was not valid for brittle materials. When ceramic slides against ceramic or enamel, wear does not occur by plastic deformation as with metals, but rather by microfracture. The crystalline composition, which includes the crystal type, content, morphology, and distribution of the crystal particle, affects enamel wear. Other factors responsible for wear are biting force, frequency of chewing, abrasiveness of diet, surface roughness, physical properties of the material, and surface irregularities, such as hard impurity particles or fine anatomical grooves, pits, or ridges. The excessive wear of tooth enamel by an opposing ceramic crown is more likely to occur in the presence of high biting forces and a rough ceramic surface.

Ghazal et al[28] suggested that the superior physical properties and surface features of zirconia enable it to maintain a smooth surface and cause less wear in comparison to feldspathic porcelain. In the present study, the zirconia crowns were fabricated using CAD/CAM technology. These zirconia crowns had homogenously distributed fine grain crystals, and the crowns were polished manually, which leads to a very smooth surface and lower coefficient of friction, causing less wear compared to feldspathic porcelain. Etman[29] supports this statement, stating that, in clinical conditions, the glaze layers have shown to be worn after 6 months and surface roughness thereby increased, causing more enamel wear of antagonistic teeth. Stawarczyk et al[30] also concluded that polished monolithic zirconia showed the lowest wear rate on enamel antagonists compared to glazed zirconia due to the lower friction coefficient. In their in vitro studies, Jung et al,[10] Preis et al,[13] and Kim et al[12] found that the zirconia causes less wear of the antagonist compared to feldspathic porcelain. These results are thus consistent with the results of the present study.

However, some of the limitations of this study include a short observation period, differing occlusal forces on premolars and molars, and differing occlusal forces even within the same tooth (more on the fossa than on the cusp). Therefore, long-term studies with larger sample sizes are suggested. It is also recommended that an examination of the adjacent dentition be performed in the future.

CONCLUSIONS

Within the limitations of the study, it can be concluded that:

- Wear of natural enamel opposing zirconia crowns was significantly less than wear of natural enamel opposing metal-ceramic crowns in the molar region after 1 year.
- Clinically and statistically significant wear were seen on natural enamel opposing natural teeth, metal-ceramic, and zirconia crowns in the premolar and molar regions after 1 year.
- Wear of natural enamel opposing metal-ceramic and zirconia crowns was significantly higher than wear of natural enamel opposing natural teeth.

ACKNOWLEDGMENTS

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Literature Abstract

Accuracy and Efficiency of 3-Dimensional Dynamic Navigation System for Removal of Fiber Post from Root Canal–Treated Teeth

The purpose of this study was to investigate the accuracy and efficiency of a 3D dynamic navigation system (DNS) compared to the freehand technique (FH) when removing fiber posts from root canal–treated teeth. A total of 26 maxillary teeth were included. Teeth were root canal–treated and restored with Parapost Taper Lux (Coltene/Whaledent) luted with RelyX Unicem (3M ESPE). A core buildup was then performed using Paracore (Coltene/Whaledent). Teeth were mounted in tissue-denuded cadaver maxillae. Teeth were divided into two groups: the DNS group (n = 13) and the FH group (n = 13). CBCT scans were taken pre- and postoperatively. The drilling path and depth were planned virtually using X-guide software (X-Nav Technologies) in both groups. For the DNS group, drilling was guided with X-Nav software, and in the FH group, under a dental operating microscope. Global coronal and apical deviations, angular deflection, operation time, and the number of mishaps were compared between groups to determine the accuracy and efficiency. The 3D volume (mm^3) of all teeth was calculated before and after post removal using the Mimics Innovation Suite (Materialise NV, Leuven, Belgium). Shapiro-Wilk, one-way analysis of variance, and Fisher exact tests were used ($P < .05$). The DNS group showed significantly less global coronal and apical deviations and angular deflection than the FH group ($P < .05$). DNS required less operation time than FH. Moreover, the DNS technique had significantly less volumetric loss of tooth structure than the FH technique ($P < .05$). The DNS was more accurate and efficient in removing fiber posts from root canal–treated teeth than the FH technique.

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Literature Abstract

Electronic Cigarettes and Oral Health

Novel nicotine products, particularly electronic cigarettes (e-cigarettes), have become increasingly popular over the past decade. E-cigarettes are sometimes regarded as a less harmful alternative to tobacco smoking, and there is some evidence of their potential role as a smoking cessation aid. However, there are concerns about their health consequences, particularly in users who are not tobacco smokers, and also when used long term. Given the mode of delivery of these products, there is potential for oral health consequences. Over the past few years, there have been an increasing number of studies conducted to explore their oral health effects. In vitro studies have reported a range of cellular effects, but these are much less pronounced than those resulting from exposure to tobacco smoke. Microbiologic studies have indicated that e-cigarette users have a distinct microbiome, and there is some indication this may be more pathogenic compared to nonusers. Evidence of oral health effects from clinical trials is still limited, and most studies to date have been small in scale and usually cross-sectional in design. Epidemiologic studies highlight concerns over oral dryness, irritation, and gingival diseases. Interpreting data from e-cigarette studies is challenging given the different populations that have been investigated and the continual emergence of new products. Overall, studies reveal potential oral health harms, underscoring the importance of efforts to reduce use in nonsmokers. However, in smokers who are using e-cigarettes as an aid to help them quit, the benefits of quitting tobacco smoking may outweigh any negative oral health impacts of e-cigarette use, particularly in the short term. Future research is needed to understand the clinical significance of some of the biologic changes observed by following different cohorts of users longitudinally in carefully designed clinical studies and pragmatic trials supported by high-quality in vitro studies.

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