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In vitro efficacy of a new approximal cleaning method - a novel interdental cleaning device for approximal plaque removal

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Running title: Interdental cleaning method and approximal plaque reduction

Conflict of interest
FR holds patents on the Interdent / Denticlean device.

Abstract

Background: The aim of this study was the assessment of a novel interdental cleaning device and an abrasive paste on approximal plaque reduction and the effects of simulated long-term use on enamel and dentin abrasion.
Material and Methods: An in vitro silicon model was used to evaluate the efficiency of plaque removal in the interdental tooth areas. After growing of a biofilm / dental plaque on extracted human teeth, these teeth were embedded into an artificial silicon model. Then a slurry of cleaning paste (marble powder/ water mixture) was moved from buccal to lingual/palatinal areas of the teeth back and forth by using a pumping device for four minutes (with appropriate volume and pressure). By sealing the occlusal spaces with the splint, the slurry could only pass through the interdental spaces. Interdental plaque was removed by the marble particles from dental enamel and dentin. Additionally, 4 years of use (2 min every day) were simulated with the same device and the abrasive changes on human dentin and human enamel were measured.
Results: A mean reduction of the plaque area to 13,5 % ± 25,8 % could be found in the approximal teeth areas. A simulation of 4 years of action showed a tooth substance loss of about 1.57 µm on dentin and 0,92 µm on dental enamel.
Conclusion: The Interdent device is a new and innovative method for approximal plaque reduction. In vitro tests for interdental plaque reduction seem promising. However, further investigations are necessary to confirm these in vitro results in an in vivo setting.

Keywords: Dental plaque, oral hygiene, tooth abrasion, in vitro, Interdent

Introduction

Caries, gingivitis and periodontitis are disorders initiated by the formation and persistence of bacterial biofilms on the hard surfaces of teeth. [1] The efficient removal of plaque is of crucial

importance in the prevention of these diseases. Interproximal areas seem to be regularly associated with higher plaque scores as these interdental areas are hard to access with a toothbrush. [2] The interdental area gives local conditions, which permit the formation and maturation of microbial plaque. Realizing ideal plaque control by tooth brushing combined with the removal of interdental plaque every 24 hours is accepted to prevent the onset of gingivitis and the establishment of approximal caries lesions. [3]

Several interdental cleaning devices as dental floss, wood sticks, interdental brushes and oral irrigators are currently found on the market. An ideal approximal cleaning device should be easy to handle, effective in the removal of plaque and additionally it should have no detrimental effect on soft and hard tissues. [3] Approximal cleaning with interdental brushes is an effective method for interproximal plaque removal. Flossing is recommended at sites with gingival and periodontal health, where interdental brushes will not pass through the interproximal area without damage. [4]

Oral irrigators are designed to disrupt and remove plaque and debris through the mechanical action of a water-jet. The exiting literature suggests that the oral irrigator as an adjunct to tooth brushing does improve gingival health more than regular oral hygiene measures or tooth brushing alone. The oral irrigator seems to flush away only loosely adhered plaque and thus affect the maturation of the microbial biofilm.[3] Tawakoli et al. found that the cleaning of interproximal regions is more efficient by utilizing an oral irrigator as compared to the use of a sonic toothbrush.[5]

The Interdent device is an alternative method for cleaning approximal / interdental spaces and uses a similar process as it would be the case for rinsing teeth after brushing. The Interdent device consists of an individualized splint and an abrasive slurry paste. Placing the splint in place seals the gaps between the maxilla and the mandible (Figure 1). The sealing of the occlusal surfaces of the upper and lower jaw achieved with the device ensures, that a water/ marble powder slurry will now mainly pass through the interdental spaces by creating a pressure in the oral cavity. The movement of the slurry through the interdental spaces will remove plaque from the approximal surfaces.

Brushing your teeth with a toothbrush is still necessary, but additional cleaning of interdental spaces by using Interdent might be an appropriate procedure to achieve an enhanced approximal plaque reduction.

The fluid movement is initiated in a more gentle way than with an oral irrigator device, because it is created with the soft tissues of the oral cavity (tongue and throat) and enhanced by the additional cleaning effect of the abrasive slurry. The marble particles in the microcrystalline cellulose in the slurry have a particle size ranging from 1 µm to 180 µm. The moohs hardness is approximately 3,5.

This in vitro study aimed to assess the efficacy of the Interdent device and paste on plaque removal and the potential abrasive side effects on the hard tissue surface of teeth.

Material and Methods

Biofilm growth

Bacteria were grown on enamel tooth surfaces attached to prepared acrylic teeth in an artificial mouth model. Six acrylic teeth in the oral model were replaced by extracted teeth without caries and fixed in the model, in order to resemble the approximal teeth areas in the mouth as close as possible. The bacteria for the biofilm growth were collected via saliva samples from two healthy donors and incubated with the appropriate supply of starch for biofilm growth in a moist environment for 48 hours. After these 2 days the plaque on human teeth (incisors and molar teeth) was stained with Mira2ton (Hager & Werken) and the teeth were placed in the prepared sockets of the oral model to mimic a correct anatomical position within the jaws.

Plaque removal

An in vitro silicon model (Figure 2) was used for the simulation of the oral cavity. Within the acrylic teeth of the lower and upper dental arch real human teeth have been used to mimic the regular plaque conditions on natural teeth. With the Interdent device the upper and lower jaw were locked and the spaces between the jaws were sealed. Then over a period of two minutes the abrasive slurry was pumped from the oral to the vestibular areas and back for approximately 240 times = two minutes of pumping. The same process as when one would rinse the teeth after brushing. The marble particles in the microcrystalline cellulose in the slurry had a particle size ranging from 1 µm to 180 µm with a moohs hardness of approximately 3,5.

Plaque assessment

The plaque on the approximal surfaces was photographed before the experiment in a standardized manner. After the application of the Interdent device and two minutes of cleaning with the abrasive slurry in the in vitro model the approximal surfaces were again photographed. The plaque areas before and after the treatment were analyzed with photoshop and the percentage of remaining plaque was calculated (Figure 3).

Abrasion on human enamel and dentin

Abrasion studies were performed in cooperation with the Institute of Material Science and Technology, TU Wien.

Thin slices of human dentin and human enamel were cut, highly polished and glued into an artificial tooth on specific areas within the approximal space (Figure 4). Half of the prepared dentin and enamel areas were covered while the other one without protection is used to investigate the abrasive behavior of the slurry in more detail on enamel and on dentin. Four years of usage was simulated in the artificial oral model. After the 4-year-simulation test the dentine and enamel loss of the unprotected area was investigated with respect to the heigt difference between the formerly protected and formerly unprotected (now, after the test-worn)

regions by using the step-height measurement method of a chromatographic, confocal profilometer Nanovea PS50. Figure 5 shows the measured surface profile. The left region refers to the during the test protected area which is used as baseline or zero level. Next to the right of the notch the unprotected worn area is located. This area is marginally lower as compared to the reference line of the protected area resulting in a step or height difference (Figure 5).

SEM evaluation of the specimen was performed at the Core Facility for applied Physics, Laser and CAD/CAM Technology (Figure 6).

Results

The application of the Interdent device with the abrasive paste resulted in high degree of interproximal plaque reduction. Only 13,5 % ± 25,8 % (n = 6) of the approximal area covered by stained plaque remained after two minutes of application of the Interdent device on plaque covered human enamel surfaces (Table 1).

In a simulation of usage of the Interdent approximal cleaning device for 4 years,
a mean loss of 1,57 ± 0,37 µm on human dentin and a mean loss of 0,92 ± 0,2 µm on human dental enamel were measured (Table 2 + 3). A calculation for the usage of Interdent for up to 70 years – assuming an almost linear trend - would result in a loss of approximately 27 µm on human dentin and in a loss of approximately 16 µm on human dental enamel.
The SEM images show no significant damage of the enamel surface after the abrasion experiments.

Discussion

The Denticlean device in combination with a low abrasive slurry resulted in 86,5 % plaque reduction in the interproximal areas of teeth in an in vitro oral cleaning model. Therefor Denticlean device helps to control amount of grown bacterial Plaque within interdental room. Goyal et al. [6] reported a 63,4 % approximal plaque reduction with a manual toothbrush and Van der Sluijs et al.[7] found a 49 % approximal plaque reduction by tooth brushing alone. Slot et al. estimated that the efficacy of plaque removal following brushing in general averages about 42 %.[8] Additionally brushing is thought to be not ideal for interproximal surfaces and more suitable for buccal, lingual and palatinal surfaces of teeth.[9] Hence interproximal cleaning is highly recommended for removal of residual plaque after regular tooth brushing. Marchesan et al. [10] reported that interdental cleaning was associated with less periodontal disease, decreased caries rates and fewer missing teeth. This stresses the importance of interdental plaque removal.

Dental floss, interdental brushes, oral irrigators, and wood sticks are at the moment the most common devices for interdental cleaning.[11]

A systematic review on dental flossing concluded that a greater part of the included studies did not show an additional benefit of flossing on the plaque scores and clinical parameters of gingivitis.[12] It is important to be aware that the weak evidence for a benefit of dental flossing on oral health should not be interpreted as evidence of a lack of effect.[10] It is up to the dental professional to determine on an individual patient basis whether high-quality flossing is an achievable goal.[12] In any case a simple and easy to perform method for cleaning the interdental space would be advantageous. The Interdent device has to demonstrate, that the encouraging in vitro results can be confirmed in clinical use.

Wolffe [13] found that subjects were only 50 % efficient in removing plaque from proximal surfaces with interdental brushes and dental floss. Interdental brushes seem to be more effective than dental floss.[14] A consensus report of the European Federation in Periodontology recommended that the use of dental floss should be limited to sites of periodontal health where interdental brushes might result in traumatic soft tissue injuries.[15] For interdental toothbrushes cleaning efficacy up to 49 % were reported.[16] However, interdental cleaning devices especially interdental brushes have a certain risk for gingival injury. Vogel et al.[16] presented in an in vitro porcine model that 26.7 percent of the surface of gingival papilla have been injured after two minutes of brushing with a manual interdental brush. This injured area increases up to 54.4 percent with a powered interdental cleaning device. Furthermore approximal cleaning with an interdental brush especially in healthy gingival conditions may result in loss of soft tissue papilla tips and thereby in reduced “red and white” esthetics.
From the mechanism of action the Interdent device is in a way comparable to an oral irrigation device. However the Interdent device has slower fluid movement and an additional abrasiveness of the slurry. Husseini et al.[17] found no beneficial effect of the oral irrigator to reduce visible plaque but found a trend to improved gingival health. Hoenderdos et al.[18] reported no effect on visible plaque control for wood sticks, but found a reduction in gingival bleeding. The clinical assessment of the Interdent device for plaque reduction in vivo and changes in gingival inflammation has to be examined in future clinical trials. The Interdent device has a certain potential for improved interdental cleaning by a kind of supported natural cleaning mechanism.

Our results show that the simulation of 4 years of use reduces 1.57 µm of human dentin and 0,92 µm on human enamel resulting in 16 µm of enamel loss and 27 µm of dentin loss over the lifetime. This enamel loss is quite similar to the lifetime´s brushing effect found in an investigation of erosion and abrasion in an in situ model by Hooper et al. [19] with 38 µm of lifetime abrasion. Bishang et al. [20] reported a loss of 21.03 µm of dentin abrasion for a sonic toothbrush and 6.13 µm for the manual toothbrush for a simulated brushing time of 8.5 years.

The loss of enamel and dentin in this in vitro investigation of the Interdent device is comparable to the amount of abrasive losses for regular tooth brushing. This and the good in vitro cleaning results might make that device a safe and efficient tool for the cleaning of approximal tooth areas.
The marble particles in the microcrystalline cellulose in the slurry have a particle size ranging from 1 µm to 180 µm and are very important for the efficacy of the Interdent device. The moohs hardness of the marble particles in the Interdent powder combination is approximately 3,5. The tooth abrasion in our in vitro cleaning experiment was in the safe range and comparable to the abrasiveness of regular tooth brushing. Because of the simplicity, the low cost and no need of electricity of the Interdent device, it could be used widely also in remote regions and it is 100% recyclable.
The SEM images of enamel surfaces show no negative effects on the investigated samples. This underlines the safety of the Interdent cleaning procedures on enamel and is particularly important for the clinical investigations that are planned in the near future.
All our data are strict in vitro results and further investigations have to assess the efficacy and the safety of the Interdent device and abrasive paste in a clinical setting.
To the best of our knowledge our investigation is the first to assess the Interdent device and the cleaning powder in vitro. Our results show that the Interdent device with the abrasive slurry is efficient in approximal plaque reduction. Approximal plaque reduction is of high importance for oral health.[10, 21, 22]. A simple and applicable way to improve interdental plaque control could have a high impact on oral health

Conclusion

The Denticlean device is a new and innovative method for approximal plaque reduction.
By reducing bacterial load in the interdental space, Denticlean device can combat and reduce the risk of dental caries, gingivitis and periodontitis in the interdental space.
The first in vitro tests seem promising for interdental plaque reduction. Further clinical and in vivo evaluations are necessary to confirm these in vitro results presented in this study.

Table 1: Plaque removal with the Interdent device

Tooth	Plaque before cleaning (Pixels)	Plaque after cleaning (Pixels)	Percentage
1	376291	27518	7,31
2	494277	15963	3,23
3	960311	6631	0,69
4	891740	8843	0,99
5	869954	25349	2,91
6	820314	541237	65,98

Table 2 : The measured value of abrasion on human dental enamel

Enamel abrasion	
1	1,221 µm
2	0,790 µm
3	0,832 µm
4	0,857 µm

Table 3: The measured value of abrasion on human dental dentin

Dentin abrasion	
1	1,844 µm
2	1,335 µm
3	1,933 µm
4	1,185 µm

Figure 1

Interdent device in vivo

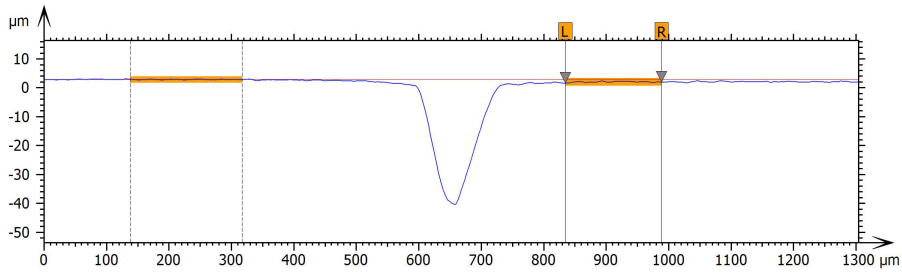
Figure 2 shows the Interdent devices and the in vitro oral cavity silicon model. The upper and lower arch of the model are interlocked by the Interdent device. The surrounding tissues are simulated by synthetic material and a pump is located at the distal part of the model in order to mimic an in vivo setting in the flow of water / marble mixture trough the interdental space and the pressure produced by the tongue in the oral cavity.

Figure 3
In vitro setting in the artificial mouth and colored bacterial plaque on human dental enamel before the cleaning tests.

Figure 4: Enamel slices built into an acrylic tooth for the assessment of abrasion over a simulated time of 4 years.

Figure 5

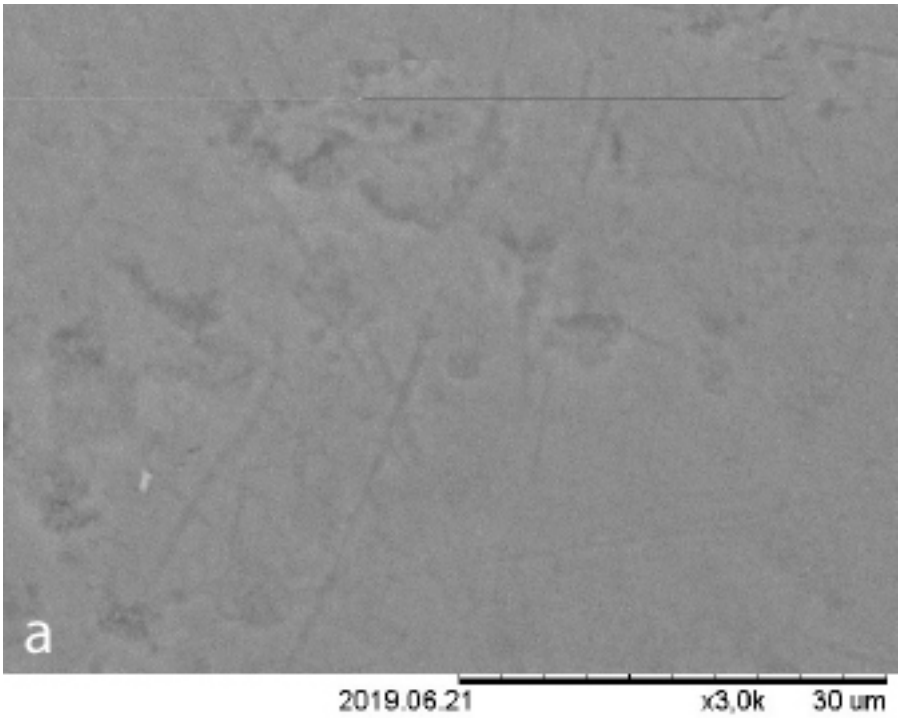
Documentation of the results on the abrasive behavior of the slurry determined by using a chromatographic confocal profilometer. Measurement of abrasive losses on human dental material samples exhibiting a protected area (left region marked in yellow) and another (unprotected) half that has to sustain the abrasive treatment of the slurry (right region)

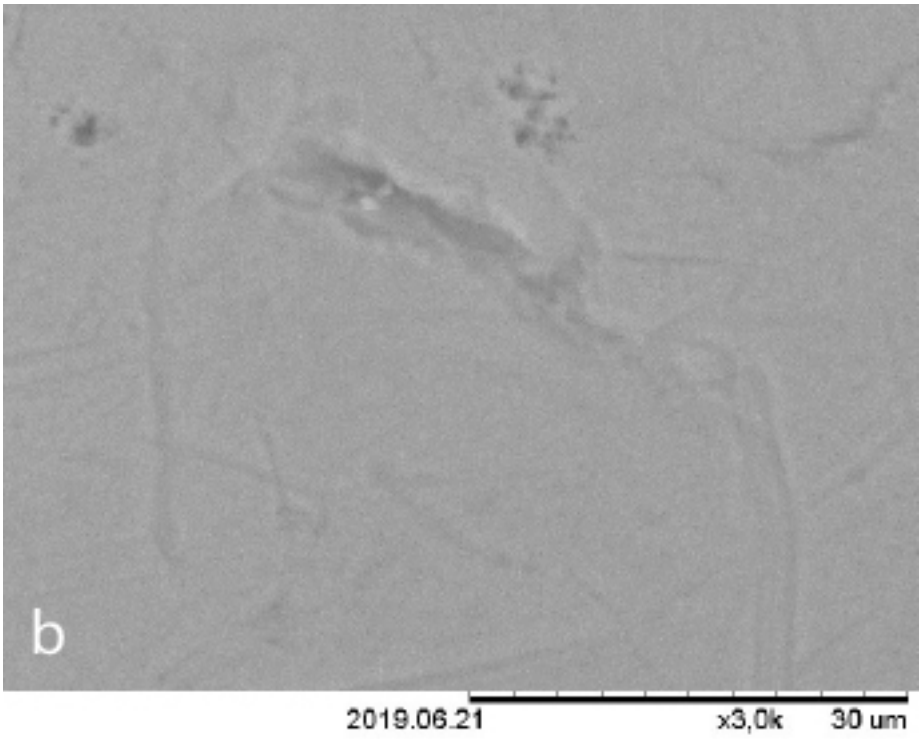


Parameters	Step 1	Unit
Width	157.125	µm
Maximum height	1.296	µm
Mean height	0.832	µm

Figure 6:

Tooth surface in 3000x magnification SEM (a) abrasivity treatment for 4 years of use, (b) covered areas of the same tooth





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