Differences in Enamel Surface Roughness Changes after Debonding Using Resin Infiltration System and Nano-Filled Resin Coating

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Abstract

Debonding and removal of adhesive remnants after orthodontic treatment will increase the surface roughness of enamel, This condition promotes plaque accumulation which leads to enamel demineralization. Analyzing enamel surface roughness changes after debonding using resin infiltration system, nano-filled resin coating, and the combination of both materials.

We also analyze the differences in surface roughness changes of enamel between the three groups. 30 extracted upper first premolar tooth specimens were bonded with standard edgewise bracket and stored in distilled-water for 24 hours.

Then, brackets were debonded and adhesive remnants were removed using highspeed dome tapered tungsten carbide bur at 30.000rpm**.** Afterwards, each specimen was randomly assigned into one of the three treatment groups (n=10), which were: resin infiltration system (R); nano-filled resin coating (N); A combination of resin infiltration system + nano-filled resin coating (RN).

The surface roughness of enamel was measured using Mitutoyo SJ-301 Surface Roughness Tester before and after the treatment. Enamel surface roughness were significantly changed in all three groups after the treatment ($p<0.05$). Enamel surface roughness of R group decreases from 0.424 µm to 0.277 µm while N group decreases from 0.421 µm to 0.202 µm, and RN group decreases from 0.419 µm to 0.162 µm. The differences in surface roughness changes between three groups were also significant ($p<0.05$). The biggest differences found in RN group (0.257 µm) resulting the smoothest surface, followed by N group (0.218 µm) and R group (0.147 µm) respectively.

A combination of resin infiltration system and nano-filled resin coating reduced the surface roughness of enamel after debonding significantly compared to resin infiltration system or nano-filled resin coating alone.

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Introduction

Fixed orthodontic appliances using brackets/bands that attached to tooth enamel is commonly used to treat malocclusion because of its popularity.[1] After the ideal occlusion is achieved, fixed orthodontic appliances is removed manually using the debonding pliers and the adhesive remnants is cleaned using rotary instrument from the tooth surface. This step is called debonding.[2]

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Several research has shown that adhesive cleaning with rotary instrument such as fine diamond finishing bur, stone polishing bur and tungsten carbide bur can cause crystal enamel demineralization, porosity and permanent damage on the tooth enamel.[3-8] This condition increases enamel surface roughness which can raise the risk of plaque accumulation.[1,2,5] Enamel surface demineralization should be balanced with the enamel surface remineralization to prevent further damage. Various kinds of methods for enamel surface remineralization have been found to improve the quality of enamel surface without having through invasive process.[9] The use of remineralization agent such as fluoride, chlor-hexidine and CPP-ACP takes up to 200 days in showing good results, hence patient cooperativity is really needed.[9,10] Newest method called resin infiltration flows directly into the capillary structure of enamel.[11-14] This technique used flowable resin to fill enamel porosity without drilling. Previous study in 2012 shows that it repairs the enamel porosity caused by white spot after debonding and reduces surface roughness of enamel, though it cannot be used on carious lesion.[14] Recent innovations in dentistry, have promoted the use of nanometer scale material in order to produce physically, chemically, and mechanically better properties.[15] Nano-filled resin coating is one of the materials that use nanometer scale. It contained nano-filled resin which can penetrate and adhere on tooth surface or any resin-based materials and enhance the properties.[16,17] To understand the performance of resin infiltration and nano coating agent, some similiarities have been found between the two. Firstly, both the materials is made of resin. They also work in same principle which is filling the porosity and repairing enamel surface damage.[16,17] Until today, there is no research comparing both of the materials on their mechanism to repair the surface roughness of enamel after debonding.

Materials and methods

The research took place in Dental Material Science Laboratorium Faculty of Dentistry University of Indonesia on September – November 2017. The population were the extracted first maxillary premolar. The sample was buccal surface of extracted maxillary first premolar. The sample consisted of 30 teeth. The samples criteria for the removed maxillary first premolar because of orthodontic purposes consists of the buccal enamel surface is relatively flat, has never been attached to bracket/orthodontic appliance, free from stain, white spot lesion, cracking, caries and other structure damaga on the buccal site of enamel, free from direct or indirect restoration, and no enamel structure anomaly, such as amelogenesis imperfecta, fluorosis, dentinogenesis imperfecta, etc.

Debonding and surface roughness of enamel measurement. Enamel specimen was made by cutting the tooth's crown and root 2mm under the CEJ using the cutting disc bur (Galaxy Cutting Wheel, Ortho Technology, USA). After that, the crown was placed on the center of PVC mould with diameter 25mm and height 20mm, the buccal site was placed horizontally under the PVC mould. Self curing acrylic was mixed and poured into the PVC. When the acrylic sets, mould PVC was detached. Every specimen was bonded with premolar standard edgewise bracket (American Orthodontics, USA) on the buccal side. Bracket mesh was slightly coated with petroleum jelly (Vaseline,USA) before bonding to prevent the adhesive attached to the bracket mesh after debonding. Bracket was bonded to specimen using Transbond XT (3M Unite, USA) according to the manual instruction. The buccal side that wasn't covered with bracket was coated with nail polish.

Specimen was soaked in aquades for 24 hours. The next step was debonding the bracket using debonding plier (Item Number 800-8034, Ormco, USA) and cleaning of adhesive remnants in enamel surface using dome tapered tungsten carbide bur highspeed 30.000rpm with mesio-distal motion. Cleaning was done when no residue of the adhesive material be seen visually and the enamel feels smooth when stroked with explorer. Specimen was divided randomly into three subjects group (10 specimen on each group), R group was applied with Icon infiltration resin (DMG,Germany), N group was applied with G Coat Plus (GC, Tokyo) nano-filled resin coating and RN group was applied with the combination of Icon resin infiltration and G Coat Plus nano-filled resin coating. All of the specimen was given treatment based on manual instructions of each the material

Enamel surface roughness value was tested before and after the treatment to the specimen using Mitutoyo SJ-301 surface roughness tester (Mitutoyo, USA) with cut off of 0.25mm and maximum length of 1.25mm. Specimen is placed as paralel as possible to the ground surface and perpendicular to stylus tip of surface roughness tester according to manual instruction.

The test was done five times in the enamel surface that was not coated with nail polish and the mean was obtained. Average value of enamel surface roughness Ra (Roughness average) was recorded in micrometer unit (μm).

Statistics Analysis. The result of this research is numeric data. The datas are tested using normality test Saphiro Wilk, Paired T-Test, Kruskal Wallis test dan Post-Hoc Mann Whitney test. The difference is considered statistically significant if p<0.0.5. Special Package for Social Science (SPSS) 23.0 version was used for data tabulation and statistics.

Results

The change of enamel surface roughness before and after the treatment to each of the specimen was tested with paired T-Test. Value of enamel surface roughness becoming smoother and statistically significant after the application of resin infiltration on R group from 0.424 μm to 0.277 μm. Value of enamel surface roughness becomes smoother and statistically significant after the application of nano-filled resin coating on N group from 0.421 μm to 0.202 μm. Value of enamel surface roughness becoming smoother and statistically significant after the application of infiltration resin and nano-filled resin coating on RN group from 0.419 μm to 0.162 μm. Statistics analysis result of enamel surface roughness before and after the treatment in each groups can be seen on table 1.

The difference in changes of enamel surface roughness between the three subject groups were tested using Kruskal-Wallis test and Post-Hoc Mann Whitney test. Enamel surface roughness value between the three groups were also statistically significant. This shows that there is a difference between the materials to change enamel surface roughness. Application of resin infiltration combined with nano-filled resin coating shows the biggest change (0.257 μm) compared to application of resin infiltration (0.147 μm) or nano-filled resin coating (0.218 μm) alone. Statistics analysis of enamel surface roughness change between the three groups can be seen on Table 2.

			Enamel Surface Roughness		p Value*
Groups	n		Mean	SD	
R	10	before	0.424	0.009	0.000
		after	0.277	0.006	
N	10	before	0.421	0.015	0.000
		after	0.202	0.007	
RN	10	before	0.419	0.007	0.000
		after	0.162	0.004	

* p<0.05 = statistically significant (t-test). R = resin infiltration. N = nano-filled resin coating. RN = resin infiltration and nano-filled resin coating

Table 1. Comparison of enamel surface rougness before and after treatment of specimen in each group

		Surface Roughness Value			p Value
Groups	n	Mean	Minimum	Maximum	
R	10	0.147	0.134	0.162	0.000*
N	10	0.218	0.194	0.252	
RN	10	0.257	0.250	0.266	

*p<0.05 = statistically significant (Kruskal Wallis and *Post-Hoc* Mann-Whitney Test). R = resin infiltration. N = nano-filled resin coating. RN = resin infiltration and nano-filled resin coating

Table 2. The difference in changes of enamel surface roughness between the three groups

Discussion

Bonding process, which includes etching; using primers and also adhesive, debonding process and cleaning of the adhesive remnants using rotary instrument can cause decay to the enamel surface.[7] However, it has been standardized on this research and the process is done only by one researcher in order to minimize bias.

In this research, the adhesive remnants in the enamel surface after debonding was cleaned using 12-blade fluted dome tapered tungsten carbide bur highspeed 30.000rpm in mesio-distal direction.[2] Highspeed handpiece was used because of the decent power it has in removing adhesive material. Dome shaped bur was chosen because it has similar shape with buccal contour of tooth. The bur was positioned parallel with teeth vertical axis and given a light pressure with one way motion during the adhesive cleaning process. This will reduce possible damage to the enamel.[4,5] Cleaning procedure was done when the adhesive material could not be seen visually and enamel surface feels smooth when stroked with explorer. [2,5]

Average value of enamel surface roughness after the adhesive cleaning in this research was 0.42 μm. This value is higher than the surface roughness threshold to prevent the bacteria adhesion in enamel surface which is 0.2

µm.[1] It means that bacteria could easily adhere on the enamel and created plaque accumulation after the adhesive cleaning was done. Increase of surface roughness value is caused by erosion mechanism using the tungsten carbide bur. Sharp side of the blade was scraping the adhesive material as well as the enamel surface.[6,7] Microscopically, damage to enamel surface is a lesion and narrow form.[4-8] Ahrari research also shows similar result, using 12-blade fluted tungsten carbide bur high-speed, the average value of surface enamel roughness after the adhesive cleaning was 0.6µm.[5]

Surface enamel roughness value after the application of resin infiltration material was 0.277 µm. The decrease of surface enamel roughness after the application of resin infiltration was caused by low viscosity and low contact point of resin matrix TEGDMA to the enamel which can diffused and flow into enamel porosity.[12,13]

It has been reported that resin infiltration can reduce surface enamel roughness after the application.[14] However, this value is still over the surface roughness threshold to the bacteria adhesion which is 0.2 µm.[1] Resin infiltration can decreases surface enamel roughness but cannot created enamel surface that can resist bacteria adhesion.

Value of enamel surface roughness after the application of nano-filled resin coating was 0.202 µm. The value is better compared to the application of resin infiltration alone. This difference may be caused by nano-filled resin coating, as it not only fills the enamel porosity but also can coated enamel surface evenly because it has nanometer filler and single-dispersion to methyl methacrylate matrix.

Methyl methacrylate also known for its ability to coat the surface evenly and prevent the formation of air inhibition coating so that the surface will be smoother.[16,17]

This value was a little bit over the threshold of enamel surface roughness which is 0.2 µm.[1]

Value of enamel surface roughness after the combined application of resin infiltration and nano-filled resin coating was 0.162 µm. This value is below the threshold for enamel surface roughness to bacteria adhesion, which is 0.2 µm.[1] Thus, combination of both materials created enamel surface that can resist bacteria adhesion and also has the smoothest surface.

Result of this research confirms the theory stated by Mueller dan Schmidlin that resin infiltration combined with resin based coating agent will result in smoother enamel surface, compared to the application of resin infiltration or nano-filled resin coating alone.[18,19]

Resin infiltration material has the lowest value change in enamel surface roughness, which is 0.147 µm. According to Rahiotis, the use of resin infiltration material only covers the enamel pore without creating new layer on the surface.[20]

Most of the resin infiltration material consist of TEDGMA matrix without filler.[21] TEGDMA causes material viscosity becoming lower and that it enhances the material ability to diffuse inside the enamel pore. This process is much easier because of the etching before the resin infiltration. Etching will open the outer part of enamel so that the enamel prism will be exposed and give a way into the infiltration resin material. This also reinforced by Ahrari, Taher, dan Schmidlin researches that shows the enamel picture after the use of resin infiltration.[5,14,19] The image of enamel surface from researchers shows that enamel surface porosity was opened before the application of resin infiltration material and seen to be closed after the material application without making a new layer on the surface.

Nano-filled resin coating has the bigger difference in value of enamel surface roughness compared to resin infiltration material which is 0.218 µm. Nano-filled resin coating is a resin consist of matrix and filler. The ability to close the porosity and gap in enamel surface is because of the filler size and viscosity of the matrix. This research used nano-filled resin coating with nano filler and has single-dispertion characteristic. This characteristic makes the nano-filled resin coating smoother because the evenly spread filler in the resin surface. Matrix on the nano-filled resin coating material is methyl methacrylate, which is known to have the ability to coat the surface evenly and prevent the formation of air inhibition layer which results in smoother surface.

Lohbauer, Khalid and GC company used Scanning Electron Microscope and stereo microscop on the surface that has been coated with nano-filled resin coating and it shows that specimen suface has evenly coated with coating agent and also free from porosity and gap. [16,17,23]

The same thing was also found in Taher's research that compared the change in enamel surface roughness after the application of resin infiltration and fissure sealant to the enamel surface. Lower surface roughness was found more on the fissure sealant material that contains more filler compared to resin infiltration material.[14]

Based on that, the conclusion was that the filler inside the resin will affect value change in surface roughness.

The biggest difference of enamel surface roughness was found in the combined application of the resin infiltration and nano coating agent which is 0.257 µm. Mueller dan Schmidlin explained that resin infiltration application to the enamel will increases enamel surface quality. However, resin infiltration has low viscosity so that it will easily causes formation of air inhibition layer which leads to the detachment of the resin infiltration. Air inhibition and detachment of resin infiltration will affect the enamel quality. Restoration on the top of resin infiltration will give the additives effect and increase the enamel quality, especially surface roughness. Application of coating agent on the top of infiltration resin will create homogenous layer that will cover all the enamel surface.[18,19]

The combination of resin infiltration and nano-filled resin coating gives the smoothest surface of enamel on this study. However, there was still a few limitation. In vitro surface roughness may be quite different compared to oral condition, especially the presence of saliva, oral temperature, and other chemical reactions. Measurements of surface roughness value that has been made in this study not described the long term effect as measurements in this study only done at one time. Future study should consider this limitation to achieve the results as close as possible to oral condition.

Conclusions

Debonding and cleaning of the adhesive remnants causes enamel crystal demineralization and damage to the tooth enamel surface. The enamel contour will be rough, which increases risk of bacteria attachment and plaque accumulation on the enamel surface. This research shows that the application of resin infiltration, nano-filled resin coating and the combination of both materials can repair and decrease the value of enamel surface roughness after debonding.

Among these three methods, the combination of resin infiltration and nano-filled resin coating shows the best result to decrease enamel surface roughness. Application of both materials results in the smoothest enamel surface.

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Declaration of Interest

The authors report no conflict of interest.

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