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Comparitive evaluation of antimicrobial effectiveness of titanium oxide coatings on different types of ceramic brackets against Streptococcus mutans

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A B S T R A C T

Aim: Nanomaterials are widely used in modern clinical dentistry. They improve various properties, such as antimicrobial properties, durability of materials. These particles do not exceed 100 nm, due to they obtain a better ratio between the surface and mass. Nanomaterials are used in many areas of dentistry, such as conservative dentistry, endodontics, oral, and maxillofacial surgery, periodontics, orthodontics, and prosthetics. One of the most important complications of fixed orthodontic treatment is enamel demineralization. Brackets and orthodontic accessories facilitate plaque accumulation and compromise oral hygiene maintenance which lead to an increase in oral bacteria count during orthodontic treatment.
Materials and Methods: 30 MBT 0.022" monocrystalline ceramic brackets and 30 MBT 0.022" polycrystalline ceramic brackets (Metro Orthodontics) which are randomly divided into 4 groups: 2 control groups (group-1=15 uncoated monocrystalline and group-2=15 uncoated polycrystalline) and 2 experimental groups (group-3=15 silver oxide coated monocrystalline and group-4=15 silver oxide coated polycrystalline).
Result: S.mutans counts were significantly less in the experimental groups than control groups.
Conclusion: Titanium oxide coatings on ceramic brackets reduced the colony forming units of S. mutans. Reduced number of colony forming units was seen in both the monocrystalline and polycrystalline coated brackets than their control groups.

1. Introduction

Nanomaterials are widely used in modern clinical dentistry. They improve various properties, such as antimicrobial properties, durability of materials. These particles do not exceed 100 nm, because they obtain a better ratio between the surface and mass. The larger the surface area of the material, the greater its reactivity. It is also easier to absorb them in the body, which can also result in high cytotoxicity.[1] According to the European Commission states that: "Nanomaterial is defined as a natural, incidental, or manufactured material containing particles, in an unbound state or as an aggregate or as an agglomerate and where, for 50% or more of the particles in the number size distribution, one or more external dimensions is in the size range 1–100 nm.[2] In specific cases and where warranted by concerns for the environment, health, safety, or competitiveness the number size distribution threshold of 50% may be replaced by a threshold between 1% and 50%". Nanomaterials are used in many areas of dentistry, such as conservative dentistry, endodontics, oral, and maxillofacial surgery, periodontics, orthodontics, and prosthetics.[3] One of the most important complications of

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fixed orthodontic treatment is enamel demineralization. Brackets and orthodontic accessories facilitate plaque accumulation and compromise oral hygiene maintenance which lead to an increase in oral bacteria count during orthodontic treatment. Application of nanotechnology in material science is a great step towards producing materials with enhanced chemical, mechanical, optical, and electrical features. The development of technology gives better opportunities to both patient and orthodontist due to new physicochemical, mechanical and antibacterial properties of nanosized materials and can be used in coating orthodontic wires, elastomeric ligatures, and brackets, producing shape memory polymers and orthodontic bonding materials.[4] Not only can we control biofilm formation, reduce bacterial activity and act anticariogenic, but also, through the desired tooth movement, shorten the treatment time.[4] Orthodontic brackets have been coated with nitrogen doped titanium dioxide. The activation of Nitrogen doped Titanium dioxide leads to the formation of OH. Free radicals, superoxide ions (O2), peroxyl radicals (HO2) and hydrogen peroxide (H2O2). These chemicals, through a series of oxidation reactions, react with biological molecules such as lipids, proteins, enzymes and nucleic acids, damage biological cell structures, but also exert antimicrobial activity.[5] Previously many studies have been done to evaluate the antimicrobial property of Titanium dioxide coated orthodontic brackets either metal or ceramic against to the common oral microbial flora like streptococcus mutans or lactobacillus acidophilus. But there is no evidence for comparison between mono and polycrystalline silver oxide coated ceramic brackets against to both the bacteria.[6] Hence, this present study is aimed to compare the antimicrobial effectiveness of different titanium dioxide coated ceramic brackets against streptococcus mutans.

2. Materials and Methods

2.1. Orthodontic materials

30 MBT 0.022” monocrystalline ceramic brackets and 30 MBT 0.022” polycrystalline ceramic brackets (Metro Orthodontics) which are randomly divided into 4 groups: 2 control groups (group-1=15 uncoated monocrystalline and group-2=15 uncoated polycrystalline) and 2 experimental groups (group-3=15 silver oxide coated monocrystalline and group-4=15 silver oxide coated polycrystalline).

2.2. Preparation of photocatalytic titanium oxide coated orthodontic brackets

Surface coating of stainless steel orthodontic brackets with TiO2 is carried out by radiofrequency magnetron sputtering method (Oerlikon Balzers Pune) by bombarding it with positive ions in the presence of argon gas discharge. A constant 7 cm distance is kept between brackets and TiO2target and the coating process is conducted for a period of 30 minutes. The brackets are placed in a vacuum chamber and are pumped down to a recommended pressure. All brackets are coated from front and back side to achieve coating of titanium in all undercuts which is present on brackets. The coated brackets is further oxidized in an open air furnace at the temperature between 500°to 700°for 5 hours to provide a thin and uniform coating of titanium oxide on stainless steel orthodontic brackets.

2.3. Bacterial strains

S. Mutans (MTCC 890) were inoculated in 5 ml of a BHI and incubated for 24hours at 37°C.

2.4. Antibacterial activity assay of orthodontic brackets S.mutans

S. mutans culture broth was diluted with BHI broth to make an optical density of 1.0 at 660 nm. Around 10 micro litre of the diluted bacterial suspension was transferred on to test tubes containing silver coated and uncoated ceramic brackets. These tubes were incubated inside the laminar air flow chamber. After incubation, 100 ml of the bacterial suspension was serially diluted and plated onto BHI agar plates. Antibacterial activity was described as the survival rate by colony-forming units (CFUs) for S.Mutans using manual colony counter.

3. Results

Test was done to assess the significance between the bacterial Mean CFU.

The mean CFU of S. mutans in uncoated monocrystalline ceramic brackets (Group 1) group is 376.38± 27.76. T test was done to assess the significance between the bacterial Mean CFU. There is statistically significant difference present in mean CFU formed ($p < 0.001$).

The mean CFU of S. mutans in uncoated polycrystalline ceramic brackets (Group 2) group is 380.71 ± 48.15. T test was done to assess the significance between the bacterial Mean CFU. There is statistically significant difference present in mean CFU formed ($p < 0.001$).

The mean CFU of S. mutans in titanium coated monocrystalline ceramic brackets (Group 3) group is 73.92±13.02. T test was done to assess the significance between the bacterial Mean CFU. There is statistically significant difference present in mean CFU formed ($p < 0.001$).

The mean CFU of S. mutans in titanium coated polycrystalline ceramic brackets (Group 4) group is 78.50 ± 12.20. T test was done to assess the significance between

Table 1: The above table shows the mean colony forming units (CFU) of S. mutans in various groups.

Group	N	S. mutans		Mean difference	t value	P value
		Mean	Std. Deviation			
Group 1	15	376.38	27.765	142.320	27.762	<0.001**
Group 2	15	380.71	48.159	137.440	17.878	<0.001**
Group 3	15	73.92	13.029	-9.760	-4.504	<0.001**
Group 4	15	78.50	12.208	-10.800	-5.504	<0.001**

the bacterial Mean CFU. There is statistically significant difference present in mean CFU formed (p <0.001).

4. Discussion

The decalcification of enamel surfaces adjacent to orthodontic appliances is an important and prevalent iatrogenic effect of fixed orthodontic appliance therapy. The bonding of orthodontic brackets has become a widely accepted procedure, which increases the number of plaque retention sites and, as result oral hygiene becomes more difficult which results in demineralization.[7,8] As enamel demineralization usually manifests itself clinically as "White spot lesion" (WSL). The WSL has been defined as 'subsurface enamel porosity from carious demineralization' that presents itself as "a milky white opacity" when located on smooth surfaces.[8]

The unbalance between enamel demineralization and remineralization usually results as a situation of "Dental Caries". The bacteria present in the plaque causes dissolution of organic acids in the enamel. The levels of acidogenic bacteria, such as S. mutans, become significantly elevated in orthodontic patients. If these bacteria have an adequate supply of fermentable carbohydrates, acid by-products will be produced, lowering the pH of the plaque. As the pH drops below the threshold for remineralization, carious decalcification occurs. With the progression of the caries, the number of streptococcus (Aerobic bacteria) decreases and that of lactobacillus (Anaerobic bacteria) increases.[9]

4.1. Ceramic brackets

Ceramic brackets were introduced in late 1980's and that they are composed of either polycrystalline or mono crystalline alumina counting on their distinct method of fabrication. The primary ceramic brackets were mono crystalline which were milled from single crystals of sapphire using dimensional tools. Later polycrystalline zirconium or zirconium are introduced to alumina ceramic brackets.

Advantages

1. Superior esthetics and enamel like translucency.
2. Better color stability.
3. Resistance to wear of deformation.

Disadvantages

1. Enhanced frictional resistance.
2. Frequent bracket breakage.
3. Iatrogenic enamel damage.
4. Difficulties in debonding.[10,11]

Surface coating of orthodontic brackets can be obtained by different methods, like physical vapor deposition, electro deposition, electroless, and metallurgical. According to Yamamoto among all, physical vapor deposition exhibits a strong antimicrobial effect. So in this study, coatings of orthodontic brackets was carried out by magnetron sputtering method which is one of the physical vapor deposition methods.[5]

The use of photocatalytic TiO2 to destroy organic compound in contaminated air or water has been studied extensively for the last 2 decades. In 1985, Matsunga and coworkers reported that microbial cells in water could be killed by contact with a TiO2- catalyst upon illumination under UV light for 20 to 60 min. Killing of cancer cells with the TiO2 photocatalyst for medical application has also been reported.[12] The photocatalytic activity of titanium oxide has been actively integrated in diverse areas such as water treatment processes, air cleaning agents & antibacterial agents (Hoffmann 1995).[13] Among various infectious microorganisms S.mutans is one of the most closely investigated microoganisms in dentistry. Previously many studies have done on photocatalytic activity of titanium oxide coatings on orthodontic brackets, which state that the application of titanium oxide can effectively prevent the adhesion of S.mutans & development of dental plaque.[14]

Titanium is considered as the most inherent and corrosion resistant materials.[15] It increases the passivating effect of stainless steel. TiO2 may be found in crystalline form as rutile and anatase. A rutile structure is considered as more thermodynamically stable than anatase structure. The coating of TiO2 to fixed orthodontic appliance can wear of due to intraoral environment as a result of unstable anatase structure. This problem can be prevented by increasing the temperature and pressure of RF sputtering unit during coating, and due to high temperature and pressure the anatase crystalline structure can be converted into rutile, for effective photocatalytic activity the crystalline structure of TiO2 is considered an important factor.[14]

The mean colony forming units (CFU) was found to be higher in uncoated monocrystalline and polycrystalline brackets (376.38± 27.76 and 380.71 ± 48.15 respectively) compared to their respective titanium oxide coated counterparts (73.92±13.02 and 78.50 ± 12.20 respectively) against streptococcus mutans (S. mutans). The reduction of S. mutans to titanium oxide coated brackets might be a result of decomposition of surface organic molecules of S. mutans such as the M-protein.[16,17] This phenomenon might further cause the cell walls of bacteria to become more fragile. Results of the present study are in concurrence with the studies by Ramazanzadeh et al, Salehi et al, and Magnusson et al. TiO2 decomposes the organic compounds in a series of oxidation reactions, leading to production of carbon dioxide.[16,18] Reactive oxygen species (ROS) like hydroxyl radicals are formed during the oxidation reactions and are responsible for bacterial inhibition.[18,19]

We found that S.mutans counts were significantly less in the experimental groups than the control groups. However, in the intra-group comparisons, the colony forming units were lesser in the coated monocrystalline group than the coated polycrystalline groups which suggests that the silver oxide coatings on ceramic brackets were more effective against S. mutans specifically the monocrystalline brackets than the polycrystalline brackets.

5. Conclusion

The following conclusions can be made from this study:

1. Titanium oxide coatings on ceramic brackets reduced the colony forming units of S. mutans based on the action of titanium oxide on S.mutans mentioned above.
2. Reduced number of colony forming units was seen in both the monocrystalline and polycrystalline coated brackets than their control groups.
3. When the two types of ceramic brackets were compared, monocrystalline coated brackets are more effective than polycrystalline coated ceramic brackets.
4. Titanium oxide coatings on monocrystalline ceramic brackets is a novel development to reduce the white spot lesions after orthodontic treatment.

6. Conflict of Interest

The authors declare that they have no conflict of interest.

7. Source of Funding

None.

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