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

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ABSTRACT

Aim: The historical aspect of nanotechnology dates back to 600 BC. Taniguchi was the first to use the term nanotechnology in 1974, originating from a Greek word meaning “dwarf”. Nanotechnology when combined with dentistry and medicine created an interdisciplinary field i.e., nanodentistry and nanomedicine and this combination gets engineers, chemists, physicians on a single platform having various applications in detection, imaging and drug delivery devices.With respect to orthodontics, the nanoparticle coated archwires, adhesives, temporary anchorage devices, brackets, orthodontic wires with shape memory and biofilm control features have been applied. Silver nanoparticles are combined with different accessory orthodontic materials which results in the addition of more antimicrobial properties which inturn decreases the biofilm formation and maintain better oral health. Antibacterial effectiveness of nanosilver coated materials has been shown with and without the release of nanosilver ions in in vitro studies. In addition, long-term inhibitory effects against S.mutans have been found while no nanosilver ions were released.
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: Silver oxide coatings on ceramic brackets reduced the colony forming units of S. mutans. Both monocrystalline and polycrystalline coated brackets showed reduced number of colony forming units than their control groups.

1. Introduction

The historical aspect of nanotechnology dates back to 600 BC. The artisans of Mesopotamia created a glittering effect on pots by using nanoparticles in 9^{th} century. Taniguchi was the first to use the term nanotechnology in 1974, originating from a Greek word meaning “dwarf”, but was popularized by Eric Drexler in his book “Engines of creation”.[1] The word nano created a seismic shift in almost every aspect of science and technology and engineering having its direct or indirect effects on day-to-day life, ethics, economics, and international relations. Nanotechnology when combined with dentistry and medicine created an

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interdisciplinary field i.e., nanodentistry and nanomedicine and this combination gets engineers, chemists, biologists, physicians on a single platform having various applications in detection, imaging and drug delivery devices.[2] The greater surface to volume ratio of nanoparticles helps in the closer interaction with microbial membranes and provides a large surface area for antimicrobial activity. With the increasing number of bacterial strains, bacteria are becoming antibiotic resistant, but this can be reduced with the use of metal nanoparticles than the conventional antibiotics.[3] Off late nanoparticles of metals or their compounds were incorporated into the restorative materials, pulp capping agents, denture base materials, implants, orthodontic appliances and oral hygiene aids.[4] In addition to improving their physico-chemical and mechanical properties, the nanoparticles of metals like silver, copper, gold, titanium and zinc are antibacterial in nature. With respect to orthodontics, the nanoparticle coated archwires, adhesives, elastomeric ligatures, temporary anchorage devices, metal brackets, ceramic brackets, orthodontic wires with shape memory and biofilm control features have been applied.[5] The antibacterial properties of silver are widely accepted in biomedicine, thus silver nanoparticles are combined with different accessory orthodontic materials which results in the addition of more antimicrobial properties which in turn decreases the biofilm formation and maintain better oral health.[6] Previously manystudies have been done to evaluate the antimicrobial property of silver oxide 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. Hence, this present study is aimed to compare the antimicrobial effectiveness of different silver oxide 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 silver-coated orthodontic brackets

Surface modification of ceramic orthodontic brackets with silver (OerlikonBalzers,Pune) oxide was carried out by Magnetron sputtering method. Sputtering process remove surface atoms or molecular fragments from a solid cathode (target) by bombarding it with positive ions from an inert gas (argon) discharge, and deposit them on the nearby substrate to form a thin film. Substrates are placed in a vacuum chamber and are pumped down to a prescribed process pressure. Sputtering starts when a negative charge is applied to the target material, causing a plasma or glow discharge. Positively charged gas ions generated in the plasma region are attracted to the negatively biased target plate at a very high rate of speed. This collision creates a momentum transfer and ejects atomically sized particles from the target. These particles are deposited as a thin film onto the surface of the substrates.

In this study, sputtering was carried out on orthodontic brackets (substrate) using silver (Ag) as the target. A plasma generated inside the vacuumized chamber ejected surface atoms from the silver target, which were sputtered onto the ceramic brackets (substrate). The distance between the substrate and the target was kept constant at 7 cm, and sputtering was conducted for a period of 10 minutes. All brackets were sputtered at the same time to achieve a thin and uniform coating of silver.

2.3. Bacterial strains

Strep. Mutans (MTCC 890) were inoculated in 5 ml of a BHI (Brain Heart Infusion) and incubated for 24 hours 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 ontotest 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

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

3.1. 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 375.38± 27.765. T test was done to assess the significance between the bacterial Mean CFU. There is statistically significant difference present in mean CFU formed ($p < 0.001$).

Table 1:

Group	N	S. mutans Mean	Std. Deviation	Mean difference	t value	P value
Group 1	15	375.38	27.765	142.320	27.762	<0.001**
Group 2	15	386.78	28.159	137.440	17.878	<0.001**
Group 3	15	80.01	12.668	-11.620	-5.256	<0.001**
Group 4	15	83.50	11.951	-18.340	-6.980	<0.001**

The mean CFU of S. mutans in uncoated polycrystalline ceramic brackets (group 2) group is 386.78 ± 28.159. 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 Silver-oxide coated monocrystalline ceramic brackets (group 3) group is 80.01±12.668. 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 silver-oxide coated polycrystalline ceramic brackets (group 4) group is 83.50±11.951. 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).

4. Discussion

Revolutions in the field of science and technology have given promising results in the field of material sciences and one such advancement is nanotechnology. Nanotechnology, which concerns structures at the Nano scale, is considered as a vital current technology of the 21st century based on its economic and scientific potential. Its application is being experimented in various domains in orthodontics, from surface coatings to development of novel materials.[7]

Orthodontic brackets are an important component in order to deliver the precise force from the wire to teeth, brackets should have the right hardness and strength. Brackets act as handles to transmit the force from the active components to the teeth. There are many types of orthodontics brackets available, but of which in regular practice are ceramic brackets, which 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.[2] 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.

4.1. Advantages

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

4.2. Disadvantages

1. Enhanced frictional resistance.
2. Frequent bracket breakage.
3. Iatrogenic enamel damage.
4. Difficulties in debonding.

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.[7]

Silver nanoparticles have been found to be effective against bacteria, viruses & other eukaryotes.[3] The use of these nanoparticles as antimicrobial agentis being done in textile industries, water treatment, cosmetics & widely in dentistry for fabrication of new materials like cements & resins (Rai M 2009, Sharma BK 2009, Bar H 2009). Nanosilver coating process as antimicrobial agent to orthodontic brackets could be helpful for the prevention of white spot lesions during orthodontic treatment.[8]

Silver has an important microbial effect. The interaction of silver with thiol groups in enzymes and proteins plays an essential role in its antimicrobial action, although other cellular components, like hydrogen bonding, may also be involved.[9] Silver has been proposed to act by binding to key functional groups of enzymes. It also causes the release of K+ ions from bacterial plasma or cytoplasmic membrane, which is a site associated with many important bacterial enzymes, thus making it an efficient target site for silver action. Size reduction of silver in nanoparticle form is an important condition for the effect of silver.[10] Smaller size provides greater surface-to-volume ratio, leading to more close interaction with microbial membrane and larger surface area for antimicrobial activity.

Nanosilver has already been in use for the treatment of burn wounds in clinical practice.[9] Currently, nanosilver is a leading subject at the field of dentistry and orthodontics.[8,11–13] The silver nanoparticles show efficient antimicrobial properties compared to other salts due to their extremely large surface area, which provides better contact with microorganisms. When nanosilver is evaluated for its antimicrobial activity, it has been observed that the nanosilver particles get attached to the cell membrane and can penetrate inside the bacteria. Cell death occurs because it disturbs the respiratory chain and leaks through the holes in the cell wall.[7,14]

Therefore, we decided to apply nanosilver for the evaluation of antimicrobial effectiveness. Orthodontic brackets coated with nanosilver may lead to a new approach and be a novel solution. Most of the in vitro studies showed that nanosilver is in interaction with the inhibition of S.mutans when used as coating on metal brackets and archwires, but there is no evidence for comparison between different types of ceramic brackets on its effectiveness on S.mutans.[8,11,15,16]

Antibacterial effectiveness of nanosilver coated materials has been shown with[17] and without[18] the release of nanosilver ions in invitro studies. In addition, long-term inhibitory effects against S.mutans[19] have been found while no nanosilver ions were released. Li et al.,[13] showed that bonding agents with nanosilver were effective against bacterial growth inhibition, not only for S.mutans present on surface, but also for the S.mutans away from the surface in the culture medium.

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 least 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. Silver oxide coatings on ceramic brackets reduced the colony forming units of S. mutans.
2. Both monocrystalline and polycrystalline coated brackets showed reduced number of colony forming units than their control groups.
3. But monocrystalline coated brackets are more effective than polycrystalline coated ceramic brackets.
4. Silver oxide coatings on monocrystalline ceramic brackets is a novel development to reduce the white spot lesions after orthodontic treatment.

6. Conflict of Interest

None.

7. Source of Funding

None.

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