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Lamination of Orthodontic Archwires- an In-Vitro Study

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ABSTARCT:-
In the field of Orthodontics, the major disadvantages are the "DURATION" which is due to "FRICTION". Though many newer methods have been introduced in recent past to overcome this problem, in form of corticotomy, piezocision etc, still the result of conventional orthodontic procedures are sometimes the best for patients. Hence, we need to improve and update the conventional orthodontics as much as possible. This study focuses on coating the commercially available archwires with nano particles, which will reduce friction to a great extent. The aim of this study was to reduce the friction in orthodontic archwires, by coating them with nano particles and thereby reduce the duration of the treatment as well.
MATERIALS AND METHODS:- *Six 0.019"× 0.025"orthodontic archwires were selected. The wires were coated with nanocremics. Samples are scanned under SEM (scanning electron microscope) to view the surface topography, and, the archwires are subjected to 3D Profiler, which gives the quantitative result of the surface roughness. RESULTS:- The results show that there is significant change in the surface roughness after the coating of nanoparticles on the archwires. The SEM images show the smoothness on the surface and 3D profiler quantifies the result with statistical significance.*
KEYWORDS:- *nano particles, accelerated orthodontics, coated archwires. Pure zirconia.*

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I. INTRODUCTION:-

During the years, evolutions in orthodontics have made the treatment procedures more efficient, reliable and various paradigm shifts have provided desired smile for the patients. But there are certain misgivings in the field of orthodontics, which pose as hindrance for further wide acceptance for certain group of patients, for whom time and duration is a major limiting factor. The common disadvantages here are the "DURATION" and "FRICTION"[1]. Though many newer methods were introduced in the recent past to solve this problem, in form of corticotomy, piezocision etc, still the result of conventional orthodontic procedures are sometimes the best for patients[2,3]. Archwires used in orthodontics, generate mechanical forces, which get mediated to the teeth through the orthodontic brackets, thereby correcting the malocclusion. The orthodontic treatment duration can be minimized, by limiting the frictional forces acting on the archwire-bracket interface[3]. Thus, efficiently minimizing the treatment duration in the end.

Nanotechnology, cosmetic surgery, laser usage, and impact of digitalization in orthodontics over the past decade, have had numerous innovations and applications, which have revolutionized multiple disciplines of medicine and dentistry. Nanotechnology has been around for many decades in different forms of utilization in field of science. However, the discovery of nanotechnology has been widely attributed to the American Physicist and Nobel Laureate Dr. Richard Phillips Feynman who presented a paper called

"There is plenty of room at the bottom" in December 29, 1959, at the annual meeting of the American Physical Society at California Institute of Technology[1]. Nano materials have been widely accepted in the recent times. Their mechanical properties involve accelarated strength hardness in lighter nanocomposites and nanomechanics of molecular structures[1, 2].

In the past, various attempts have been conducted to enhance the mechanical properties of orthodontic archwires by altering the surface texture and thereby achieving wires with lesser frictional forces. These attempts had their own limitations due to technique sensitive reasons, hence newer methods are still under research and development conditions[4].

This study focused on introducing newer method to reduce friction during the orthodontic treatment. Coating orthodontic archwires with nanoceramic particles have proven to be beneficial. But the technique of coating these particles using SOLGEL procedure[5] etc had their own disadvantages that of being easily

perishable. In this study, we have used the EBPVD (electron beam vaporization deposition) technique to coat the nano particles, which is much more stronger and adherent to the archwire surface. This cutting-edge technology shall bring about revolutionary changes in the field of Orthodontics.

The main aim of this experiment was to develop an innovative method of coating archwires with nano form of pure zirconia which is hypothesized to improve the surface roughness, make it even and thereby reduce friction during retraction, which can significantly reduce the overall treatment duration.

II. MATERIALS AND METHODS:-

For this in-vitro study, three types of base metal alloys which are commonly used in the field of Orthodontics archwires, namely Nickel titanium (NiTi), Stainless steel (SS), and TMA (Titanium molybdenum alloy). All three types of archwires were taken in 0.019x0.025 cross section(ORMCO, CA, USA).

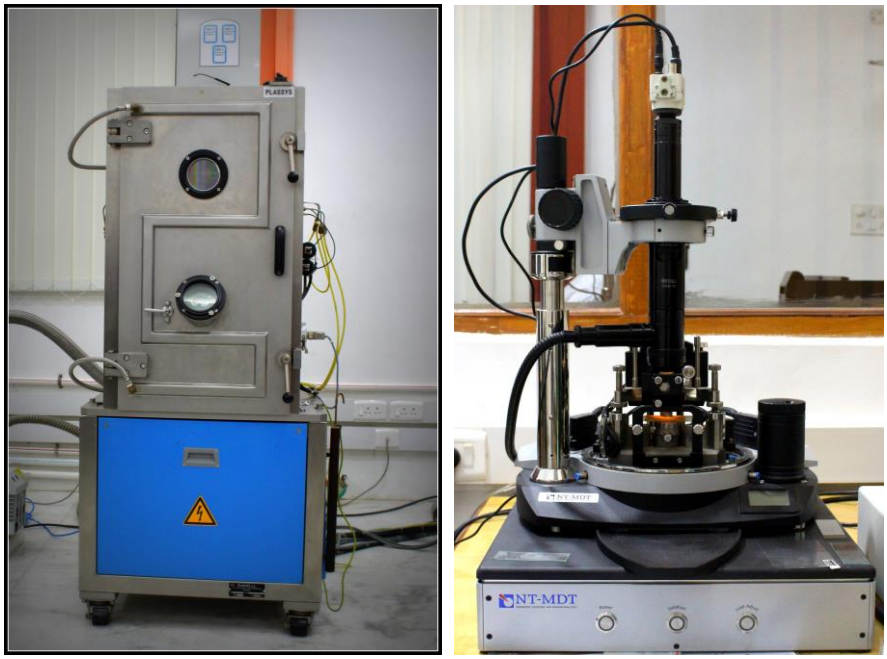
The archwires were divided into 2 variables. 6 archwires of each group was selected for coating with nano particles and the other 6 were kept as control samples.

Specimen preparation

EB-PVD (Electron beam physical vaporization deposition) technique using the instrument (PLASSYS MEB600, France) exhibited a good surface finish and an even microstructure. During this procedure, the EB-PVD technique was applied to deposit pure Zirconia (Zr) (thicknesses of 500 nm) on coated grouped archwires and then the effects were examined using Atomic Force Microscope.

A. Electron beam physical vaporization:-

The EB-PVD is a complex procedure in which a focused high energy electron beam is directed to melt and evaporate the target material (pure Zr milled in tablet form in the vaccum chamber which gets deposited on the substrate (Archwires). The vacuum pressure was set at 2□10-6 mbar and the current 180 mA. The commercially available orthodomtic Archwires were secured on the jig before being coated with pure zirconia nano particles.



B. Atomic Force Microscope:-

Atomic Force Microscope (NTMDT Ireland) provides three-dimensional surface images of the sample with high resolution.

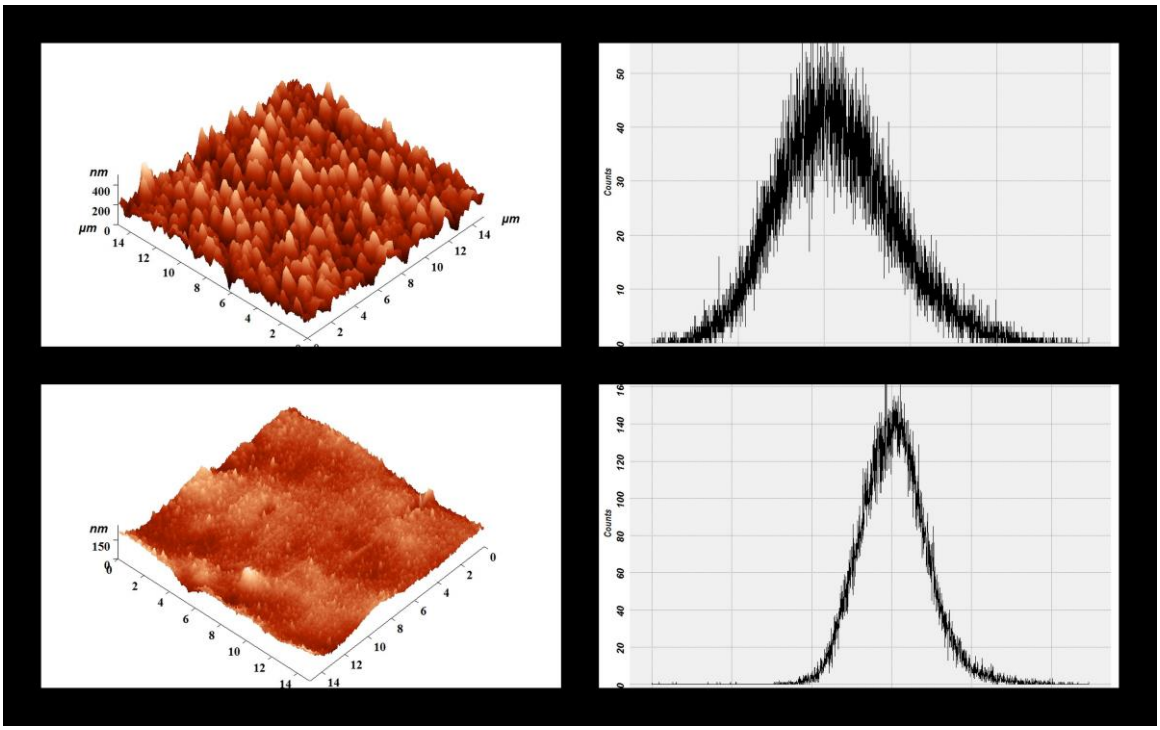
The surfaces of each sample were tested under three different areas of magnification, being 15x15µm, 10x10µm and 5x5µm to evaluate their surface roughness characterstics.

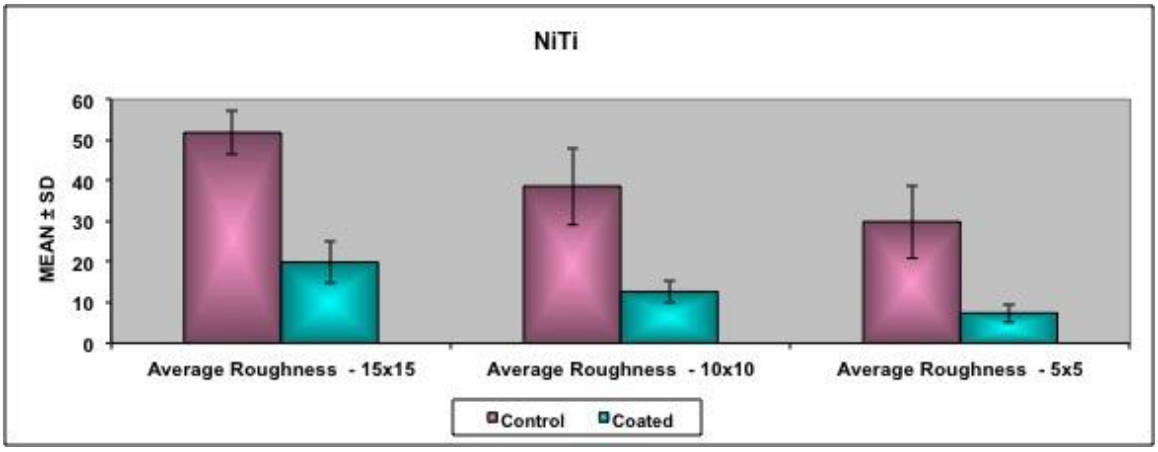
III. RESULTS:-

The coated and control samples of NiTi, SS and TMA wires were tested under atomic force microscope at three different magnification levels to evaluate the average roughness present in both groups. Results were tabulated. The achieved results were statistically analysed. Student T test for each group of variables, and the results were considererd significant if the *p value was <0.05.*

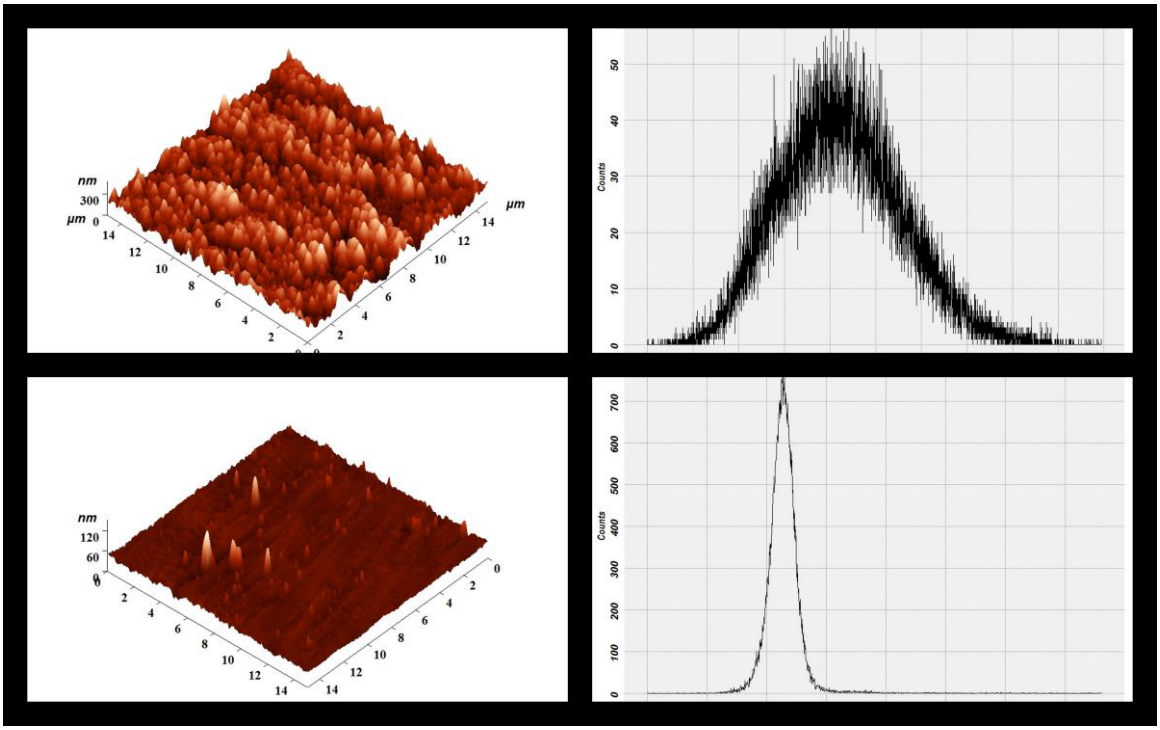
Nickel Titanium samples:-

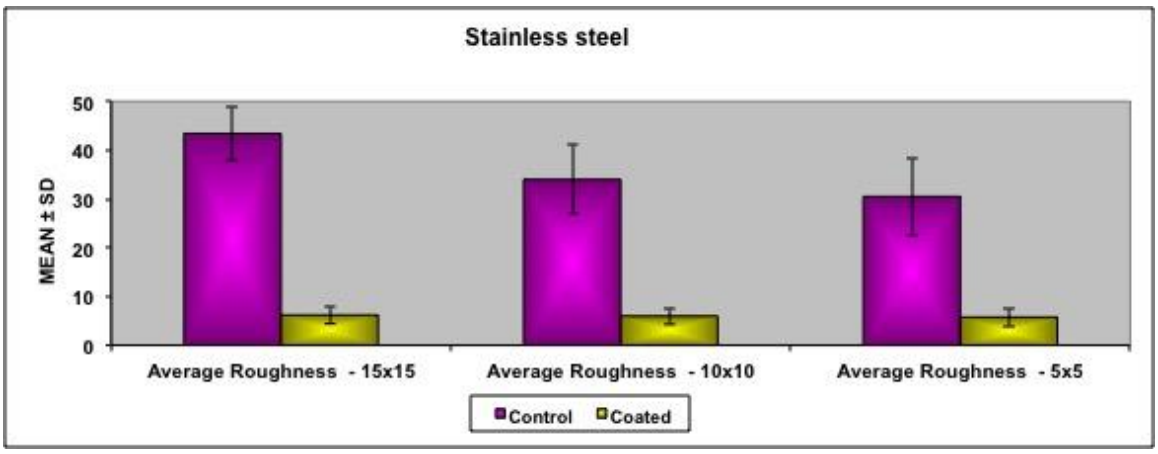
In the achieved results it was evident that, there was statistically significant reduction in the surface roughness characteristics between the control and coated groups. This is been further emphasized by the topographic images





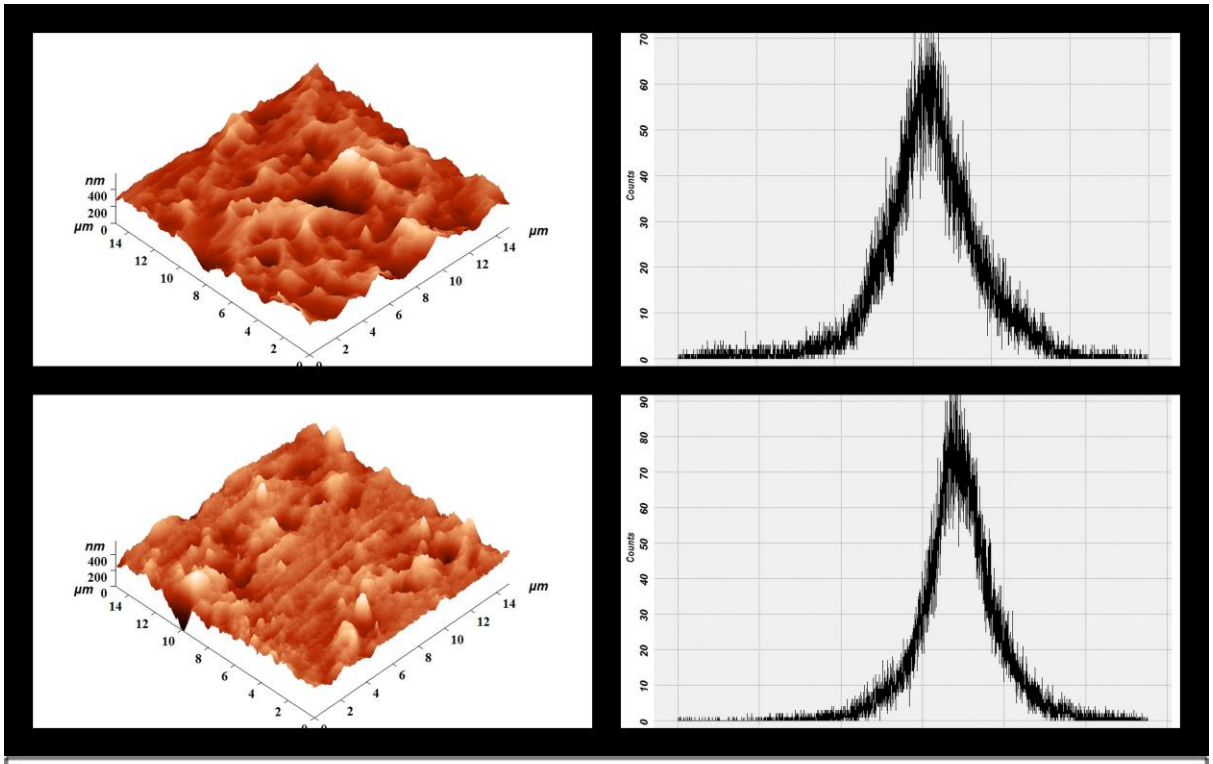
SS samples:-
On comparing the coated and the control groups there was statistically significant reduction in the surface roughness characteristics.

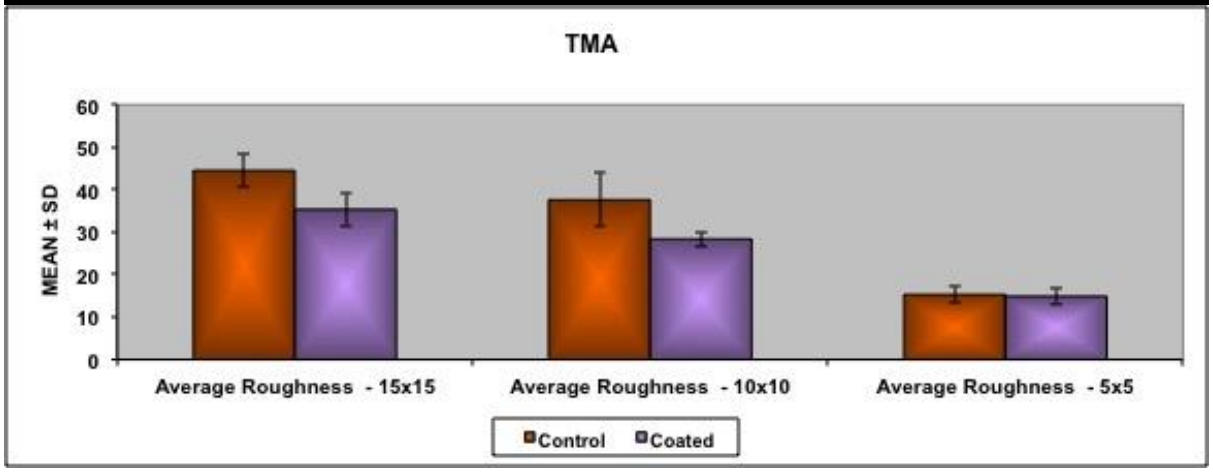




TMA samples:-
Whereas in TMA group the surface roughness was improved in 15X15 and 10X10 magnification but in 5X5 magnification, the TMA wires did not exhibit any change in their surface roughness in comparison between coated and control groups. This is been further emphasized by the topographic images.

The results obtained and their statistical analyses state that there is significant reduction in the surface roughness between the control and coated samples of Nickel Titanium and stainless steel orthodontic wires. Whereas, in the Titanium molybdenum alloy, moderate difference is found at the level of 15x15 and 10x10 micrometer magnification but no significant difference in surface roughness was evident at 5x5 micrometer magnification.





IV. DISCUSSION:-

Orthodontic treatment has been evolved over a century and the newer advancements have always withstood the test of time.

The main motto of this study was to coat the commercially available orthodontic archwires with nano particles, which have hypothesized to reduce the surface roughness of the wires, thereby minimizing the possible friction during the fixed appliance treatment[6]. Nanotechnology is described as the interdisciplinary science of the creation of materials at the nanoscale. In simpler terms can be described as as the ability to work at atomic, molecular, and supramolecular levels[7].

Various studies have been performed to assess the difference in surface roughness between the archwire alloys in general, but there are not many studies who have done nano coating on the same archwire alloys before assessing their surface roughness[8]. Whereas in this study, we have not only coated the archwires with nano particles, but have also assessed their surface roughness using atomic force microscope, and compared between them.

From the currently performed study, it has been successfully proven that orthodontic archwires can be coated with nano ceramic particles using EBPVD method, which is much more stable compared to the primitive sol-gel technique of coating. This electron beam vapourization deposition technique, although time consuming, still is more adherent to the surface of the archwire, compared to other techniques, which lead to removal of the layer with a mild scratch test

Keeping all this in mind, this study was initiated as a pilot study, to evaluate the surface roughness of the nanocoated archwires in orthodontics. Three commercially available Orthodontic archwires of 19X25 cross section were taken into consideration and divided into 3 groups, of NiTi, Stainless steel (SS) and TMA. The archwires were coated using nano form of pure zirconia particles. The coating procedure was done under EBPVD (electron beam vapourization deposition technique). Later, these wires were scanned under AFM (atomic force microscope) to evaluate the surface roughness which was compared with non-coated control samples.

The results obtained were statistically signified, and it showed that there has been significant improvement in the surface roughness of the nanocoated wires in the NiTi and SS groups, whereas, not much of significant change in the roughness in the TMA groups of wires.

As quoted in various other literatures, SS wires have higher strength and low friction compared to TMA wires[9, 10]. Since SS wires are most commonly used for retraction and space closure purposes, it is a further adding "feather on the cap" fact for stainless steel archwires, which have shown significant amount of reduction in their surface roughness characteristics after being coated with nano form of pure zirconia particles in this study[11].

The results of this study were in accordance to an article by Govindkutty et al, who performed a study on the Properties and Surface Characteristics of three archwires of different alloys[12]. Their results concluded that stainless steel with high values for strength, low friction, and an almost smooth surface continues to be the mainstay archwire in orthodontic mechanotherapy. Though the TMA wires are kinder to the tissues by generating low, consistent forces, yet the friction at the bracket-archwire interface is higher in TMA wires due to increased surface roughness in the slot base[13, 14].

The uniqueness of this study is that we have used, pure zirconia in nano form to coat the archwires, where zirconia is a tried and tested and proven biocompatible material in the dental field. After the coating, the archwire doesn't change in apparence which is a positive point. Although TMA wires did not improve in their surface roughness characterstics, as much as in SS groups, still TMA wires have significantly improved compared to their own uncoated samples.

Though this study has proven that SS wires show least surface roughness after coating the pure zirconia nano particles, still this has to be further proven with future studies, which shall assess the frictional resistance of the wire, and also the sustainability of the coating done on the wire.

V. CONCLUSION:-

This shall remain prudent to conclude by mentioning that NiTi and SS wires can be successfully coated using pure zirconia nano particles which can significantly reduce the surface roughness and thereby minimize the friction caused at the bracket archwire interface, which can be greatly beneficial for orthodontic treatment mechanics.

LEGENDS FOR ILLUSTRATIONS:-

Figure 1:- EB-PVD (Electron beam physical vaporization deposition) machine (PLASSYS MEB600, France).
Figure 2:- Nano form of pure zirconia milled into tablets.
Figure 3:- Orthodontic archwires secured and mounted on the jig.
Figure 4:- Atomic Force Microscope (NTMDT Ireland).
Figure 5:- Graphical representation of comparison between coated and control groups in NiTi samples.
Figure 6:- Topographic representation of comparison between coated and control groups in NiTi samples.
Figure 7:- Graphical representation of comparison between coated and control groups in SS samples
Figure 8:- Topographic representation of comparison between coated and control groups in SS samples.
Figure 9:- Graphical representation of comparison between coated and control groups in TMA samples
Figure 10:- Topographic representation of comparison between coated and control groups in TMA samples.

Table 1:- Comparison of surface roughness between coated and control groups of NiTi Wires
Table 2:- Comparison of surface roughness between coated and control groups of SS Wires
Table 3:- Comparison of surface roughness between coated and control groups of TMA Wires.

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