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Comparison of Implant Drill Wear along Different Surgical Sleeves- An In-Vitro Study

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Abstract

Background: Surgical drills tends to wear during implant site preparation through different surgical sleeves and the degree of wear changes accordingly. Unassessed repetitive usage of drills will eventually hinder the surgical site preparation and post operative implant integration. The purpose of the study was to evaluate and compare the wear of stainless steel pilot drills in polyurethane bone replica implant site preparation alongside three different surgical guide sleeves.

Methods: Three models of edentulous mandible of 85.85mm width*74.72mm depth*52.31mm height were designed and printed with polyurethane to simulate jaw bone. CAD CAM milled zirconia and polyamide sleeves were fabricated using STL Files of scanned stainless steel guide sleeves and were incorporated into auto polymerising polymethylmethacrylate templates. Four pilot drill bits were used with one as Control and three other drill bits were grouped into B,C and D with three different guide sleeves of twelve number each. Qualitative and Quantitative wear of the drills were analysed using scanning electron microscope and atomic force microscope. The statistical analysis used for mean comparison was One-way ANOVA.

Results: The qualitative analysis of wear along the surface of the drills are illustrated in SEM images. The amount of wear along control drill was found to be 111.905 deg. The wear along side the surface of the drills drilled through Stainless steel, Polyamide and zirconia guide sleeves were found to be 109.121 deg, 109.257 deg and 108.734 deg respectively.

Conclusion: The wear of the drills were higher in stainless steel and zirconia sleeves in descending quantitative order. The Polyamide sleeves caused least wear on the drill.

Keywords: surgical drills, stainless steel, zirconia, polyamide

INTRODUCTION

Rehabilitation of edentulous space is currently being fulfilled by use of dental implants. Dental implants are preferred owing to their ability to replace only the missing teeth without altering the adjacent natural teeth. Though dental implants are the most prioritized replacement option in the recent years the success of an implant osseointegration is influenced not only by the adequate surgical procedures and prosthetic restoration but greatly by the ideal positioning and angulation of the determined implants. A misaligned implant would pose biological and technical complications over period of time [1].

Prosthetically driven implant positioning is essential to achieve esthetic and dynamic implant supported prosthesis [2]. Conventional periapical and panoramic radiographic evaluation were insufficient to plan an implant position as they provide two -dimensional image details without accurate measures of the bone volume.

Advancements in digital technologies act as a precise guide. Evolution of implant planning software, cone beam computed tomography, image-guided template production techniques and guided implant surgeries have inherently enhanced accuracy in implant positioning with regards to both prosthetic and anatomical parameters [3].

Digitally printed surgical guides are an integral part of the successful treatment outcome. It minimizes the clinical complication to the least possible. The templates or surgical guides are used to decipher accurate details from the desired surgical treatment plan to reality [4]. A good surgical guide is one that allows for accurate desired position of implants along the predetermined insertion path with adequate stability during osteotomy.

Rapid advancements of CBCT scans (cone beam computed tomography) are used to fabricate the surgical templates using stereolithographic surgical guide techniques and navigation optical tracking techniques that are then mounted along with guide sleeves designed employing Implant planning software. These surgical templates and guide sleeves are essential tools in guided implant surgeries as they provide better veracity in implant angulations and positioning [5-8].

The position of the guide sleeves is determined from three-dimensional computer image of patient jaw and duplicate image of patient denture that has been coated with radio opaque barium sulfate. The desired mesio- distal and bucco-lingual angulation of the guide sleeves are obtained from a diagnostic arrangement with proposed trajectory that are then indexed with adjacent natural teeth in partially edentulous patients. The guide sleeves restrain the position of 2mm or 3mm drills with proposed trajectory during implant site preparation [9]. However, the drill design, material and excessive use will greatly influence the trajections of the surgical drills over a period of time[9,10].

The scuff along the surface of surgical drill bits and guide sleeves will alternatively influence the itenary of the proposed path of implant position, thereby altering the desired angulations with simultaneous increase in heat production altering the biological characteristics of the bone segment.

Stainless steel guide sleeves are commonly being used during guided surgeries, oxide zirconia based ceramic sleeves and stainless steel coated titanium nitride sleeves were developed improvising the biomechanical properties of a guide sleeve. Repetitive usage of drills will cause the drill bits to wear off reducing their cutting efficiency. The shape, sharpness, speed of the drills and amount of applied axial loads will clout the degree of abrasion along the surface of the surgical drill bits [10,11]. Abrasion of the drill bits is influenced by the mechanical properties of the guide sleeves along which they are transitioned in guided implant surgeries. Abrasion of the surfaces in drill bits are found to be associated with generation of heat during osteotomy site preparation which may contribute to biomechanical alterations in implant site.

Limitation in mechanical properties of stainless steel sleeves and zirconia sleeves lead the investigators to a newer sleeve made of polyamide. Polyamide has proven to have higher wear resistance and better properties. Therefore, comparative evaluation of the mechanical properties of the three materials, could provide a better knowledge and bring about enhancement in clinical outcome.

MATERIALS AND METHOD

Cone beam computerized tomography of a sixty years old individual with edentulous model was formatted in HTML and was converted into STL format for 3D designing. Three models of edentulous mandibles of 85.85mm width *74.72mmdepth *52.31mm height were designed and printed with polyurethane to simulate implant site preparation. Stainless steel surgical guide sleeves of 6mm outer diameter,2.2mm inner diameter and 7mm height were procured and the STL file design of the sleeves were fed digitally into CAD-CAM machine (Zircorn®) and designing of polyamide and zirconia sleeves were done and milled from polyamide blocks and zirconia blocks respectively. A surgical template was fabricated with self-cure PMMA resin with 8mm diameter to incorporate the guide sleeves from left mandibular second molar(37),left mandibular first molar(36),left mandibular second premolar(35),left mandibular first premolar(34) ,left mandibular canine (33),left mandibular lateral incisor (32),left mandibular central incisor (31), right mandibular central incisor (41),right mandibular lateral incisor (42), right mandibular canine (43),right mandibular first premolar44,right mandibular second premolar (45), right mandibular first molar (46), right mandibular second molar (47) tooth region and the sleeves were stabilized with additional self-cure clear PMMA resin. Surgical template was made to simulate clinical implant placement procedure (Fig.1). Thirty-six guide sleeves were fabricated with twelve under three different groups and were subjected to wear using three pilot drill bits in each respective group.

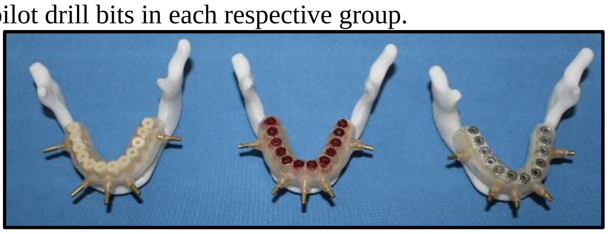

Figure 1 : Surgical templates prepared to simulate implant placement

GROUP A (Control)	GROUP B	GROUP C	GROUP D
Stainless steel drill bit with no guide sleeves	Stainless steel drill bit (n=1) with stainless steel guide sleeves (n=12)	Stainless steel drill bit (n=1) with polyamide guide sleeves (n=12)	Stainless steel drill bit (n=1) with Zirconia guide sleeves (n=12)

Group A (Control) consists of stainless- steel pilot drill bit that was cross sectioned and subjected to Scanning electron and Atomic force microscopic analysis before commencement of perforations. Group B, C, D consists of stainless-steel pilot drill bits (three) with stainless steel, polyamide and zirconia guide sleeves of twelve number in each group respectively.

The clinical implant placement procedure was simulated. Physio dispenser was used with speed of 1000 rpm and 600-700 torque. The pilot drill bit (Group A) of 2mm was cross sectioned and subjected for SEM and AFM analysis for qualitative and quantitative assessment of structural characteristics before usage of the drill bits. Stainless steel drill bit (Group B) was then directed along the surgical template with the stainless-steel guide sleeves for five complete perforations in each sleeve summing up for sixty perforations when subjected through all twelve sleeves . Stainless steel drill bits(Group C and Group D) were subjected through poly amide and zirconia guide sleeves respectively for five complete perforations in each sleeve adding up for sixty total perforations in each group. The wear of the stainless steel bits along the surface following sixty perforations through each group of guide sleeves (Group B, Group C, Group D) were then assessed using SEM (Scanning electron microscope) analysis and AFM (Atomic force microscope) analysis after cross sectioning the drill bits. Qualitative analysis of amount of wear was assessed using scanning electron microscope and quantitative analysis was done using atomic force microscope.

RESULTS

Quantitative and qualitative analysis of surface roughness along the drills and sleeves were done using Atomic Force Microscope and Scanning Electron Microscope respectively. The roughness quotient of the drills were assessed using AFM and are tabulated in Table 1and 3. The characteristic topographic changes along the surface of the drills were evaluated using SEM and are illustrated in figure 2. The roughness values along the guide sleeves were also assessed using AFM and SEM analysis and tabulated in Table 2. Based on statistical results tabulated in Table 4,5 it was found that stainless steel drill along polyamide sleeves showed greater wear resistance than stainless steel drill along zirconia and polyamide sleeves. On mean comparison of roughness values along the sleeve surfaces, polyamide showed least wear resistance than stainless steel and zirconia sleeves, thereby indicating that zirconia sleeves have wear resistance similar to stainless steel sleeves that have higher wear resistance.

Table 1 Roughness quotient for Control group

Group	Drill	Drill roughness
Group A	Stainless Steel	111.905

Table 2. Roughness quotient for experimental groups

Group	Drill	Drill roughness	Sleeves	Sleeve roughness
			Stainless steel	
			1	12.735
			2	12.714
			3	12.364
			4	11.917
			5	11.812
Group B	**Stainless steel**	**109.121**	6	12.841
			7	12.491
			8	13.11
			9	13.011
			10	12.421
			11	11.919
			12	12.531
			Polyamide	
			1	2.587
			2	2.714
			3	1.991
			4	1.899
			5	2.212
Group C	**Stainless steel**	**109.257**	6	2.464
			7	2.394
			8	2.515
			9	2.857
			10	2.719
			11	3.149
			12	3.411
			Zirconia	
			1	11.753
			2	10.92
			3	10.111
			4	10.531
			5	11.651
Group D	**Stainless steel**	**108.734**	6	11.712
			7	11.597
			8	11.666
			9	11.812
			10	11.941
			11	10.981
			12	11.691

Table 3 Drill roughness values for various groups

Group	Drill roughness
Control	111.905
Stainless steel	109.121
Polyamide	109.257
Zirconia	108.734

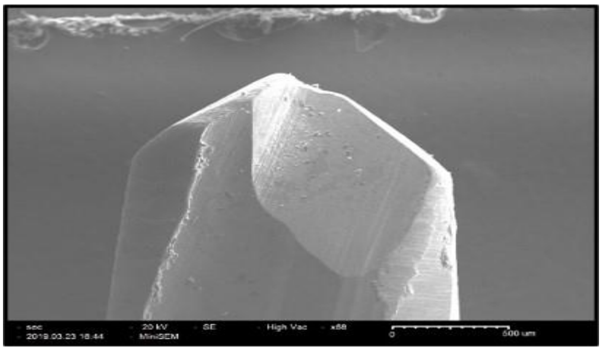

Figure 2 A : Stainless drill bit -before drilling

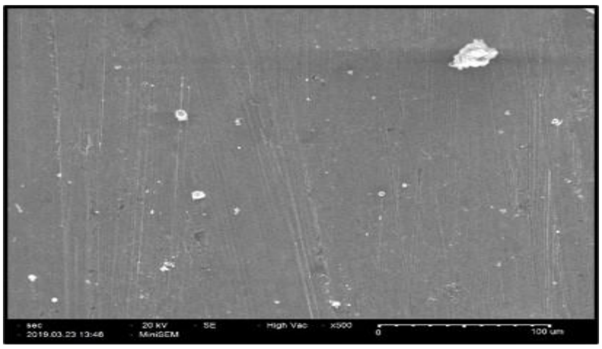

Figure 2 B: Stainless steel guide sleeve – before drilling

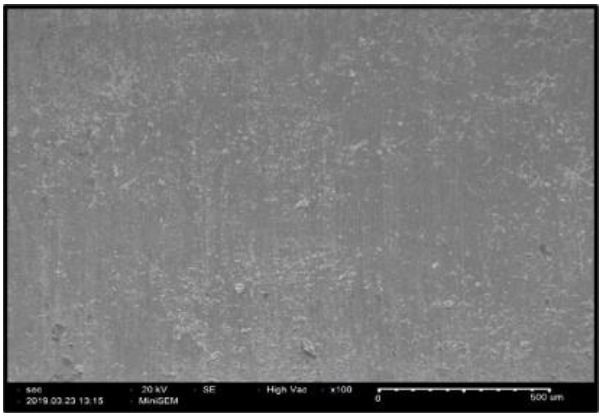

Figure 2 C: Zirconia guide sleeve- before drilling

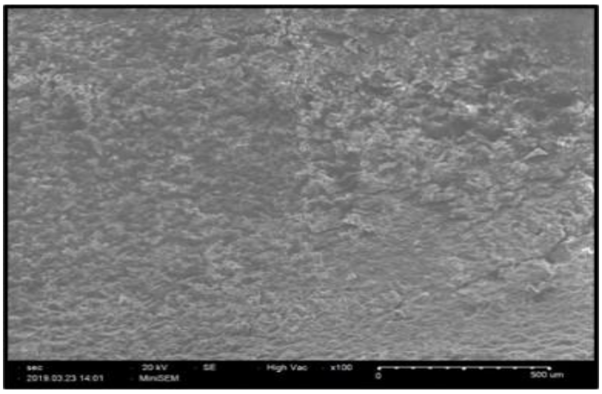

Figure 2 D: Polyamide guide sleeve- before drilling

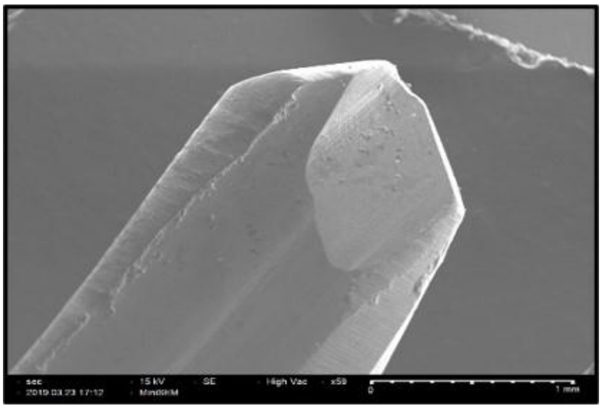

Figure 2 E : Stainless steel drill bit – after drilling

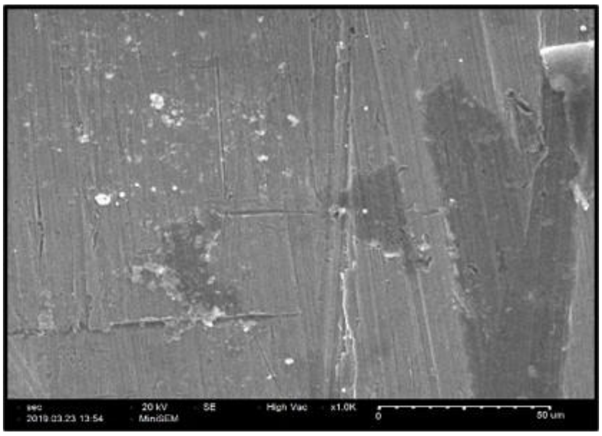

Figure 2 F: Stainless guide sleeve -after drilling

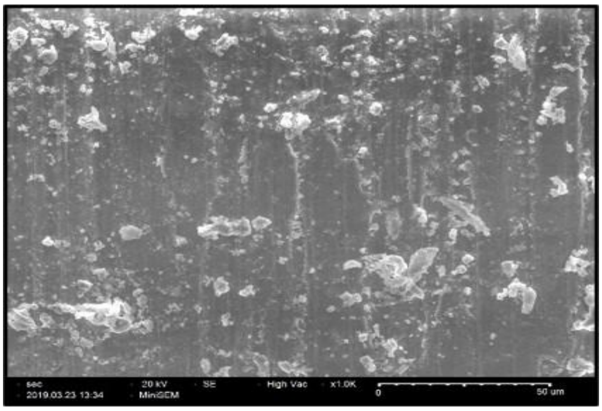

Figure 2 G: Zirconia guide sleeve- after drilling

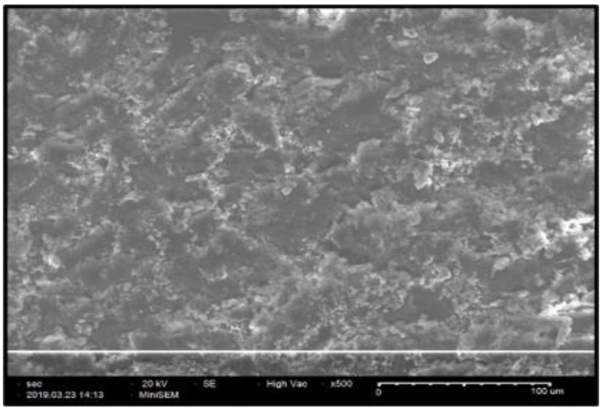

Figure 2 H: Polyamide guide sleeve -after drilling

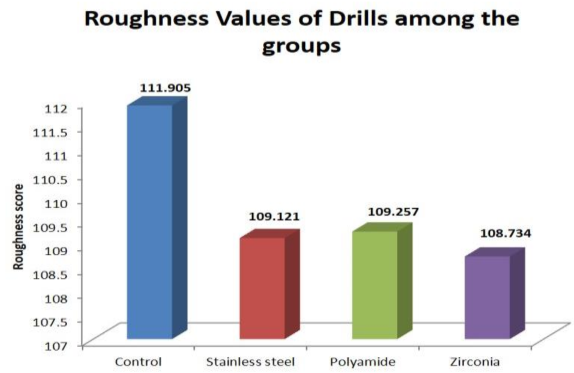

Figure 3 : Roughness values of drill among groups

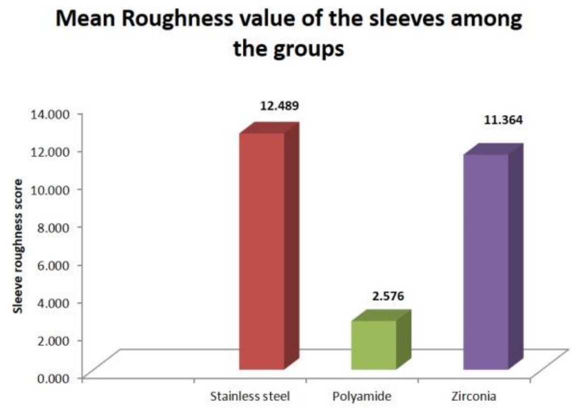

Figure 4: Mean roughness value of sleeves among the groups

Table 4 Mean comparison of sleeve roughness between the groups

Group	Mean	Std. Deviation	F value	p value
Stainless steel	12.489	0.429		
Polyamide	2.576	0.440	1476.557	.000
Zirconia	11.364	0.584		

Table 5 Post hoc comparison

Group 1	Group 2	Mean Difference	Std. Error	p value	95% CI	
					Lower Bound	Upper Bound
Stainless steel	Polyamide	9.913	0.200	0.000	9.423	10.403
	Zirconia	1.125	0.200	0.000	0.635	1.615
Polyamide	Zirconia	-8.788	0.200	0.000	-9.278	-8.298

DISCUSSION

Guided implant procedures are being greatly practiced because of their advantages in providing better accuracy and trajections during the osteotomy site preparations using the surgical guide templates [12,13,22,25]. Guided surgery involves use of guide sleeves that allow implant placements in predetermined positions [11,14,17-19,23,24] However, the materials used in fabrication of guide sleeves should have higher fracture resistance and minimal surface roughness so that their use can be clinically implicated [22]. Stainless steel introduced into dentistry in the year 1919, has evolved and marked its implications in various fields. Guided surgery involves the use of guide sleeves fabricated with stainless steel as it has higher fracture resistance, higher strength and high temperature resistance [9,22]. S.C.Mohlhenrich et.al[10], have reviewed various articles to determine the wear and temperature changes seen during drilling the osteotomy sites using stainless steel drill bits. They have concluded that the stainless-steel drill bits can undergo up to 50 drillings and have good wear resistance and they can be autoclaved.

Materials used for fabrication of implant surgical drill bits and guide sleeves are generally stainless steel. Although, Zirconia as a choice of material for fabrication of drill bits are under testing in invitro studies [8], further studies are yet to be completed for its clinical implications. The primary requisite for a material to be used as a guide sleeves is, it should not cause wear along the surfaces of the guided drill bits. Wear of stainless steel and zirconia drill bits have been assessed when drilled though bovine or porcine bone suggesting that zirconia can be used as an alternate material option [8]. As the invitro studies have been conducted using bovine and porcine bone its results are limited in clinical co-relations. Mohlhenrich et al, have done the simulation of human bony architecture using polyurethane material that may duplicate the D1 quality of bone[10] .Oliveira et al, in their previous studies have assessed the wear of stainless-steel drill bits when drilled directly into the replicated implant sites [8]. As incidence of guided surgeries are increasing, the properties of the materials used as surgical drill bits and guide sleeves should also be determined.

In the present study, the wear resistance of the stainless-steel drill bits that are being commonly used in guided surgeries were determined when drilled along the guide sleeves of three different materials. Based on the power of study, we have categorized twelve samples in each group for four different groups with one control and three experimental groups. The groups were categorized as Group A (One Stainless steel drill bit-Control), Group B (One Stainless steel drill bit and twelve stainless steel guide sleeves), Group C (One Stainless steel drill bit and twelve Polyamide guide sleeves) and Group D (One Stainless steel drill bit and twelve Zirconia guide sleeves).The drill bits were initially drilled along the surface of the guide sleeves embedded within polyurethane mandibles to simulate implant osteotomy site and were then subjected to quantitative and qualitative analysis to determine the degree of wear along the stainless steel drill bits of all four groups and also along the different guide sleeves.

The qualitative analysis of the surface changes before and after the procedure was analyzed using the Scanning electron microscope [SEC mini Sem, model: SNE-3200M] (Fig.2). The SEM images reveal topographic alterations in the surface of the stainless-steel drill bit passed along the guide sleeves. Both the drill bits and the guide sleeves have shown characteristic alterations over their surface. The quantitative roughness quotients (Rq) i.e. degree of wear resistance, was analyzed using the Atomic force microscope [XE7-Park Systems, Korea.] . The drill bits, guide sleeves were sectioned in flat surfaces to accustom to the microscopic dimensions. The quotient values were analyzed using the Wsxm software from the microscopic images. The results showed that the roughness quotient for the control group A was 111.905 deg.(Table 1) The Rq value for stainless steel drill bit drilled along the stainless-steel sleeves in group B, was 109.121 deg. The Rq values of stainless steel drill bit used along the zirconia guide sleeve was 108.734deg. and was found to be less compared to the drill bits drilled through stainless steel and polyamide sleeves suggesting that the wear of stainless steel drill along the surface of zirconia is more while compared to the wear of the drill bits when drilled through polyamide and stainless steel sleeves. Friction between two different metals could be the reason to accentuate the wear over their surfaces. Polyamide being a synthetic polymer did not abrade the surface of the drill bits thereby providing a higher Rq value of 109.257 deg. for the corresponding drill bit. Movement of the stainless steel drill bit along the surface of the stainless steel guide sleeve caused abrasion along the surface of both the components, and the Rq value of the drill bit i.e. the amount of wear along its surface is high compared to the abrasion along the surface of the drill bit perforated through zirconia and polyamide sleeves . (Table2,3) (Fig.3)

The wear of zirconia, stainless steel and polyamide guide sleeves were also determined in this study using SEM and AFM analysis. The guide sleeves were also categorized under groups A, B, C, D with group A being the control group and Group B, C, D being the experimental groups. The three different groups of guide sleeves were segregated among the Groups B, C, D and were subjected to microscopical analysis following osteotomy procedure. The quantitative analysis of degree of wear along the surface of guide sleeves was done using Atomic Force Microscope and subsequent results were obtained (Fig.4).

Among the samples in Group B (Stainless steel sleeves), the roughness quotient was found to be highest in the eighth sample with 13.11deg and least in fifth sample with 11.812 deg. of wear, whereas among the samples in Group C (Polyamide Sleeves) twelfth sample showed the highest value of 3.41 deg while the least Rq value was seen in fourth sample with 1.899 deg. The Roughness quotient Rq values among the samples in Group D (Zirconia sleeves) was found to be highest in the tenth sample with value of 11.941 and least in third sample with 10.111deg.

On comparing the mean sleeve roughness between the three groups with one way ANOVA, the difference between the three groups was found to be statistically significant with F value of 1476.557 at *P* value of 0.000.(Table 4) Comparison of the mean difference between stainless steel and polyamide, stainless steel and zirconia and polyamide and zirconia sleeves with post-hoc test, revealed all the values to be statistically significant, implying that stainless steel is better than polyamide and zirconia, with zirconia better than polyamide in terms of being used as separate guide sleeves.(Table 5)

From the overall results, comparing the wear of the stainless steel drill bit among all the groups, it is found that the wear of stainless steel drill bit when passed alongside the polyamide guide sleeves showed the least wear along the surface whereas, the stainless steel drill bits that were passed alongside the stainless steel sleeves and zirconia sleeves showed higher degree of wear due to the friction between materials with similar properties.

It can be concluded that stainless steel drill bits do abrade when passed alongside the different materials with least being alongside polyamide, but it’s advantage of being used repeatedly for multiple cycles (sixty drillings) is justified by its property of high wear resistance.

Zirconia, evolving as a newer material is analyzed to have wear resistance similar to the stainless steel implicating its advantage of being used in clinical situations. Yet further long term and clinical studies are required to substantiate the use of zirconia as a guide sleeve in clinical scenarios.

CONCLUSION

Within the limitations of the study, it can be concluded that stainless steel drill tend to wear off when used for more than 60 drillings along the stainless steel and Zirconia surfaces whereas their surface was not altered along the polyamide sleeves, thereby indicating that Stainless steel and Zirconia sleeves were found to be wear resistant than the polyamide sleeves which was found to be least resistant. From the study, it can be suggested that Zirconia can be used as an alternate choice for the fabrication of guide sleeves.

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