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Comparative evaluation of apical debris extrusion with rotary and reciprocation instrumentation with and without irrigant activation: An in-vitro study

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Abstract
AIM: To evaluate and compare the apical debris extrusion in human mandibular molars instrumented with two different instrumentation; with and without irrigants activation.
Method: A total of 60 extracted human mandibular molars were sectioned and randomised into 4 groups, rotary without sonic activation 1A,rotary with sonic activation1b,reciprocation without sonic activation2A and reciprocation with sonic activation2B instrumentation was done with copious irrigation of 5ml of saline and active according to manufacturer instruction with the section samples mounted in Myers and Montgomery following instrumentation apically extruded debris were collected and dried in Eppendorf tubes are weighed using electronic microbalance, extruded debris weight was calculated by subtracting the weight of Eppendorf tubes with extruded debris from the mean weight of empty Eppendorf tubes, results were tabulated and The data follows Non Normal distribution. Hence Non parametric tests of significance were applied. Kruskal Wallis Anova test was applied for comparison between 4 groups; Comparison between 2 groups was analysed using Mann Whitney U test. A $p<0.05$ was considered as statistically significant and $p<0.01$ as highly significant.
Results: Rotary instrumentation with protaper gold resulted in higher debris extrusion compared with reciprocation, irrigant activation increased the debris extrusion, irrigant activation resulted in increased debris extrusion.
Conclusion: The tooth instrumented with rotary instrumentation technique showed higher apical debris extrusion despite of instrumentation techniques irrigant activation resulted in increased amount of debris extrusion.

Keywords: Rotary, reciprocation, irrigant activation, apical debris

Introduction

Achieving success in endodontic treatment requires thorough cleaning of the root canal system, both mechanically through endodontic files and chemically through irrigating solutions. However, during canal preparation, there is always a possibility of extrusion of irrigants, dentinal chips, necrotic tissue, pulp remnants, and microorganisms into the periapical region. This extrusion is largely influenced by instrumentation techniques and can result in inflammation and even treatment failure [1]. Essentially, endodontic instruments act like a piston, pushing debris through the apical foramen. When bacteria and their byproducts are forced into the peri-radicular tissues, they can trigger acute inflammation, postoperative pain, flare-ups, and may delay healing. The severity of this response depends on factors such as the amount of extruded debris, the virulence of the microorganisms involved, and the host's immune defence [1].

It has been consistently shown that all instrumentation systems are associated with some degree of bacterial extrusion beyond the apical foramen, even when preparation is kept short of the apical constriction. However, the quantity of extruded debris varies depending on the technique used. Therefore, it is crucial to adopt methods that minimize extrusion during root canal instrumentation.

Among the different approaches, the crown-down technique has been found to result in less extrusion compared to other techniques[2]. By preparing the coronal third of the canal before working toward the apical area, this method facilitates smoother debris removal and provides an easier path for irrigants to flow coronally rather than being forced apically. In contrast, techniques that employ a filing or linear motion are more likely to produce blockages and apically extruded debris due to the piston-like action of the instruments.

Rotary instrumentation utilises continuous clockwise rotation for canal preparation, while reciprocating instruments employ a back-and-forth, unequal motion (clockwise/counterclockwise).

Reciprocation is often favoured for potentially reduced torsional stress, instrument fatigue and minimal debris extrusion.

Alongside instrumentation strategies, the activation of irrigants has become a vital adjunct in modern endodontics. Sonic and ultrasonic activation systems enhance the penetration, agitation, and efficacy of irrigant solutions within the root canal system. These systems generate acoustic streaming and cavitation effects, which help to dislodge debris, biofilms, and tissue remnants from areas inaccessible to files, such as lateral canals, fins, and isthmuses. By improving the cleaning potential of irrigants, sonic and ultrasonic activation not only enhance disinfection

This study intends to evaluate apically extruded debris of rotary and reciprocating instrumentation techniques in curved root canals using rotary files Pro Taper Gold and reciprocation files; WAVE ONE GOLD with and without sonic activation

- **Material and methodology**

Source: Extracted human teeth of age group between 30 to 50 years will be collected and stored in formalin

Materials

- Airotor (NSK)
- Burs (Mani, Prime Dental Products Pvt. Ltd, India)
- K Files - #10,15 & 20 files (Mani, Prime Dental Products Pvt. Ltd, India)
- Single use disposable syringe (Unolok syringe 2.5ml, India)
- Irrigants: Normal Saline
- Apex Locator (DentaPort mini ZX, J Morita)
- ProTaper Gold rotary files (Dentsply Sirona)
- Wave One Gold
- Endomotor (triautozx II J.morita)
- Eppendorf tubes
- Silicon impression material
- Glass vial
- Distilled water
- Electronic microbalance
- Diamond Disk

Inclusion criteria

- Mesial roots of extracted mandibular molars with mature apices and patent root canals
- Root curvature between 10 to 20 degrees (According to Schneider's method)

Exclusion criteria

- Teeth with external/internal/apical root resorption
- Teeth with developmental defects
- Endodontically treated teeth
- Root canals with calcifications

A total of 60 extracted human mandibular molar tooth are collected and stored in formalin ;Mesial roots of extracted mandibular molars with mature apices and patent root canals and Root curvature between 10 to 20 degrees are selected; decoronated to 12 mm, and working length established using electronic apex locator. Each sample is allotted a number from 1 to 60. Samples collected are randomly divided into two experimental groups (n = 30) according to the rotary and reciprocating systems to be used.

Group 1: Rotary instrumentation

1. **Group 1A:** SAMPLE NO 1-15 – PROTAPER GOLD
2. **Group 1B:** SAMPLE NO 16-30 – PROTAPER GOLD with sonic activation

Group 2: Reciprocating instrumentation
Group 2A: SAMPLE NO 31-45 - WAVE ONE GOLD
Group 2B: SAMPLE NO 46 – 60 – WAVE ONE GOLD with sonic activation

The initial diameter of apical foramens was the same as the #20K-file. Each tooth was cut in half buccolingually at the furcation area and the mesial half of the tooth was separated. Radiography was done proximally to confirm the existence of two separate canals in the mesial root.
First, root surfaces were cleaned and debrided using a periodontal scaler. Then, all caries and previous fillings were removed and standard access cavities were made using round diamond burs at a high speed and under air-water spray cooling.
This study was done on the mesiobuccal canal. A stable reference point was established on all teeth flattening of mesiobuccal cusp tip as well as the same working length for all specimens.
A #10 K-file was used visually to control the apical patency and to determine the working length. The working length was measured one millimetre less than the point that was touched by the file tip in the apical foramen.
Group 1 Protaper gold instrumentation was done till F2 according to manufacturer instruction with copious irrigation of hypochlorite and final irrigant as EDTA followed by saline wash
Group 2 wave one gold instrumentation was done till small according to manufacturer instruction with copious irrigation of hypochlorite and final irrigant as EDTA followed by saline wash
Sonic activation of the prepared canals are done with 1ml of EDTA according to manufacturer instruction followed by saline wash with 2ml and activated with 1ml of sodium Hypochlorite followed by saline wash with 2ml
In the end, tooth were removed from the Eppendorf tube and that attached debris was washed from the root surface in a tube using 1 ml of saline. To achieve dry debris, the tubes were removed from the setup and were put in an incubator at 70 °C for 5 days. The specimens were dried and weighed under the same condition. The debris were weighed three times by an operator who was totally blind about experimental groups. The mean of these measurements was considered to be the new weight of the tubes. Subtracting the weight of the empty tube, the net weight of debris was achieved.
The teeth were positioned in the experimental setup proposed by Myers and Montgomery Eppendorf tubes were used to gather debris Each tube was weighed three times using an electronic semi-micro balance with an accuracy of 0.1 mg and the mean weight was recorded and summarized

Debris extruded = weight of Eppendorf tube with debris-mean weight of empty Eppendorf tubes

Statistical Analysis: The data was analysed using SPSS Version 26.0 software. The data was checked for Normal distribution using Kolmogorov Smirnov and Shapiro Wilk tests. The data follows Non Normal distribution. Hence Non parametric tests of significance were applied. Kruskal Wallis Anova test was applied for comparison between 4 groups i.e. PTG, WOG, PTG + activation and WOG + activation. Comparison between 2 groups was analysed using Mann Whitney U test. A $p<0.05$ was considered as statistically significant and $p<0.01$ as highly significant.

Null Hypothesis
There is no difference in the mean weight of Apically Extruded Debris between 4 groups.

Alternative Hypothesis
There is a difference in the mean weight of Apically Extruded Debris between 4 groups.

Results: Irrespective of the instrumentation techniques used there is significant apical debris extrusion and the activation of irrigants' increased the debris extrusion

Table 1

Tests of Normality							
	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	p value	Statistic	df	p value
Apical debris	PTG	.266	15	.005 HS	.811	15	.005 HS
	WOG	.249	15	.013 S	.806	15	.004 HS
	PTG + Activation	.259	15	.008 HS	.793	15	.003 HS
	WOG + Activation	.249	15	.013 S	.833	15	.010 S

HS – Highly significant at p<0.01; S – Significant at p<0.05

The Tests of Normality shows data is not Normally distributed (p<0.01, 0.05). Hence Non parametric tests of significance were applied.

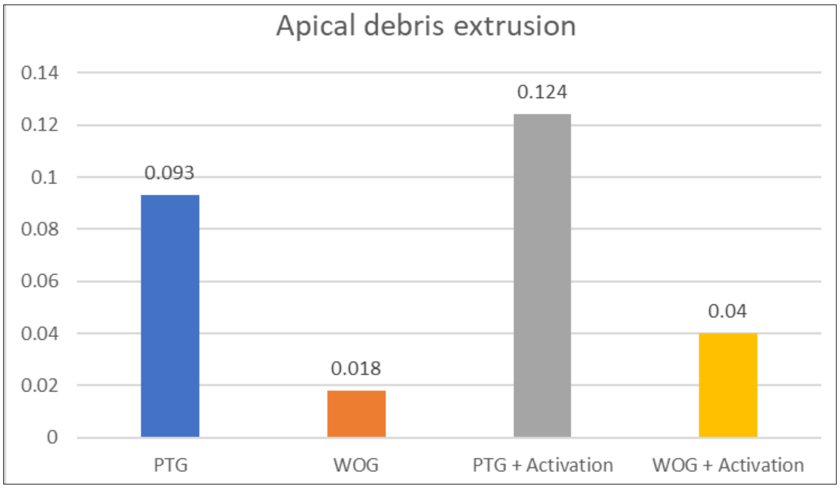


Table 2: Comparison of apical debris extrusion between PTG, WOG, PTG+Activation and WOG + Activation.

	N	Mean	Std. Deviation	Mean Rank	Kruskal Wallis H value	p value
PTG	15	.093	.026	39.53	52.69	0.000 HS
WOG	15	.018	.007	8.60		
PTG + Activation	15	.124	.021	51.40		
WOG + Activation	15	.040	.010	22.47		

Statistical test applied: Kruskal Wallis Anova; HS- Highly significant at p<0.01

The mean and SD value of PTG is 0.09±0.02; WOG is 0.018±0.007; PTG+ activation is 0.124±0.02 and WOG+activation is 0.04±0.01. Highly significant difference was observed between them. The mean value of PTG+activation is highest followed by PTG, WOG+activation and least for WOG.

Table 3: Comparison of apical debris extrusion between PTG and WOG

	N	Mean	Std. Deviation	Mean Rank	Mann Whitney U value	p value
PTG	15	.093	.026	23.0	0.00	0.000 HS
WOG	15	.018	.007	8.0		

Statistical test applied: Mann Whitney U test; HS- Highly significant at p<0.01

The mean value of PTG is significantly very high compared to WOG (p-0.000)

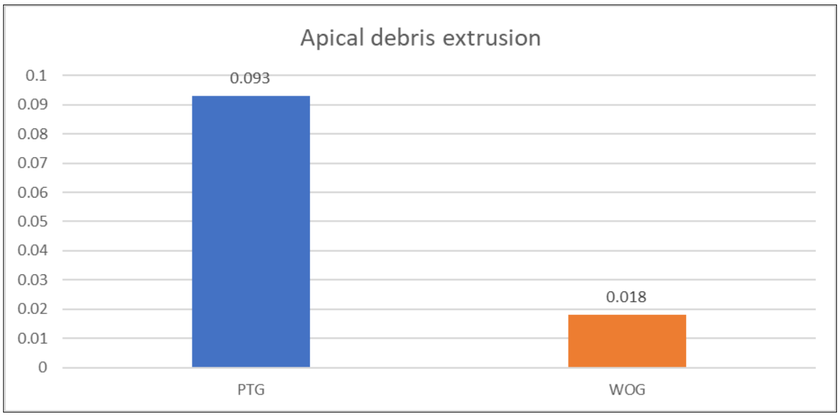


Table 4: Comparison of apical debris extrusion between PTG and PTG+Activation

	N	Mean	Std. Deviation	Mean Rank	Mann Whitney U value	p value
PTG	15	.093	.026	9.6	24.0	0.000 HS
PTG + Activation	15	.124	.021	21.4		

Statistical test applied: Mann Whitney U test; HS- Highly significant at p<0.01

The mean value of PTG+activation is significantly very high compared to PTG+activation (p-0.000)

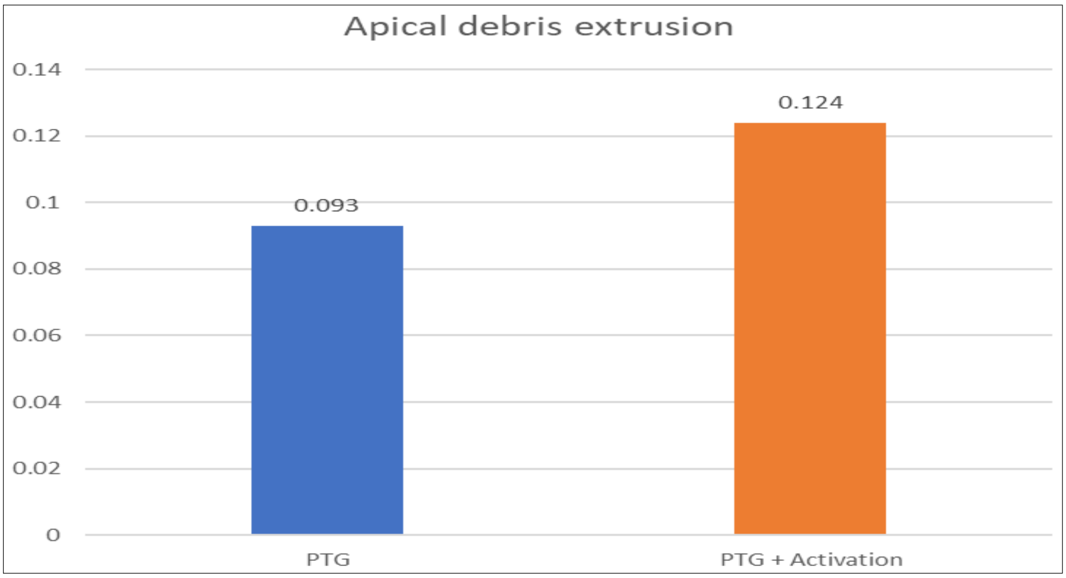


Table 5: Comparison of apical debris extrusion between PTG and WOG + Activation

	N	Mean	Std. Deviation	Mean Rank	Mann Whitney U value	p value
PTG	15	.093	.026	22.93	1.000	0.000 HS
WOG + Activation	15	.040	.010	8.07		

Statistical test applied: Mann Whitney U test; HS- Highly significant at p<0.01

The mean value of PTG is significantly very high compared to WOG+ activation (p-0.000)

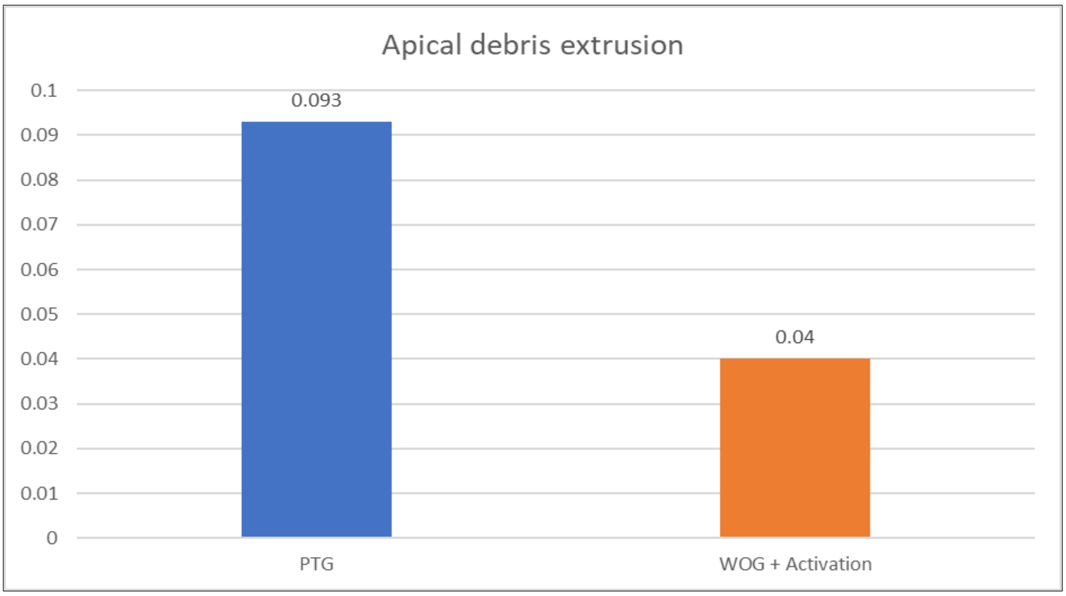


Table 6: Comparison of apical debris extrusion between WOG and PTG+Activation

	N	Mean	Std. Deviation	Mean Rank	Mann Whitney U value	p value
WOG	15	.018	.007	8.0	0.000	0.000 HS
PTG + Activation	15	.124	.021	23.0		

Statistical test applied: Mann Whitney U test; HS- Highly significant at p<0.01

The mean value of PTG+activation is significantly very high compared to WOG (p-0.000)

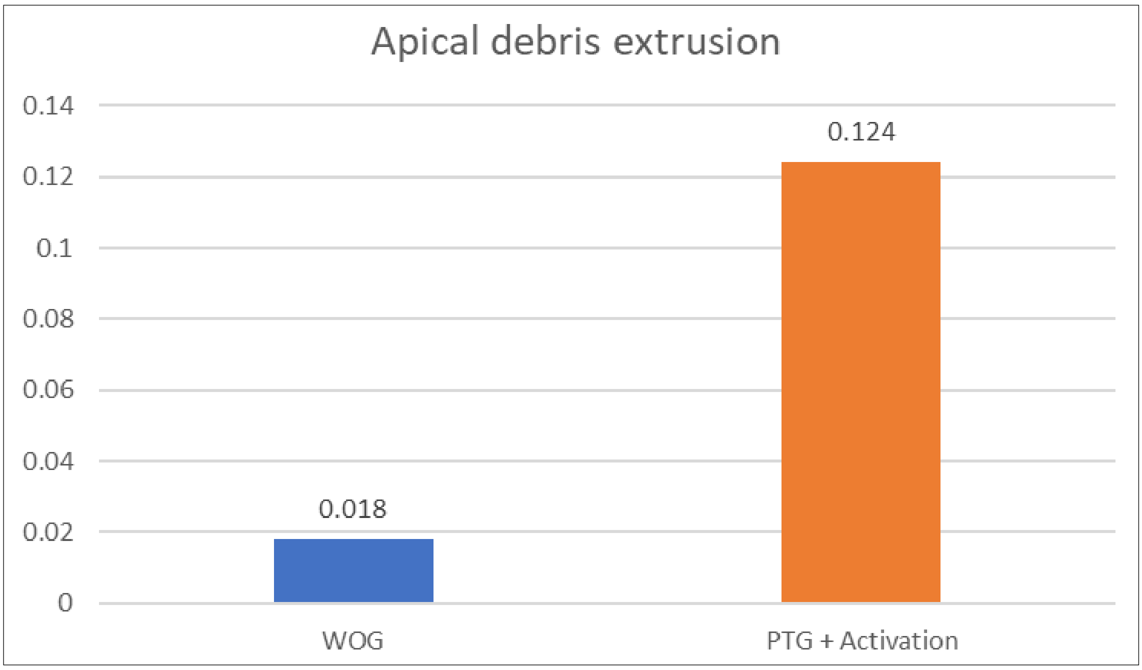


Table 7: Comparison of apical debris extrusion between WOG and WOG + Activation

	N	Mean	Std. Deviation	Mean Rank	Mann Whitney U value	p value
WOG	15	.018	.007	8.6	9	0.000 HS
WOG + Activation	15	.040	.010	23.0		

Statistical test applied: Mann Whitney U test; HS- Highly significant at p<0.01

The mean value of WOG+activation is significantly very high compared to WOG (p-0.000)

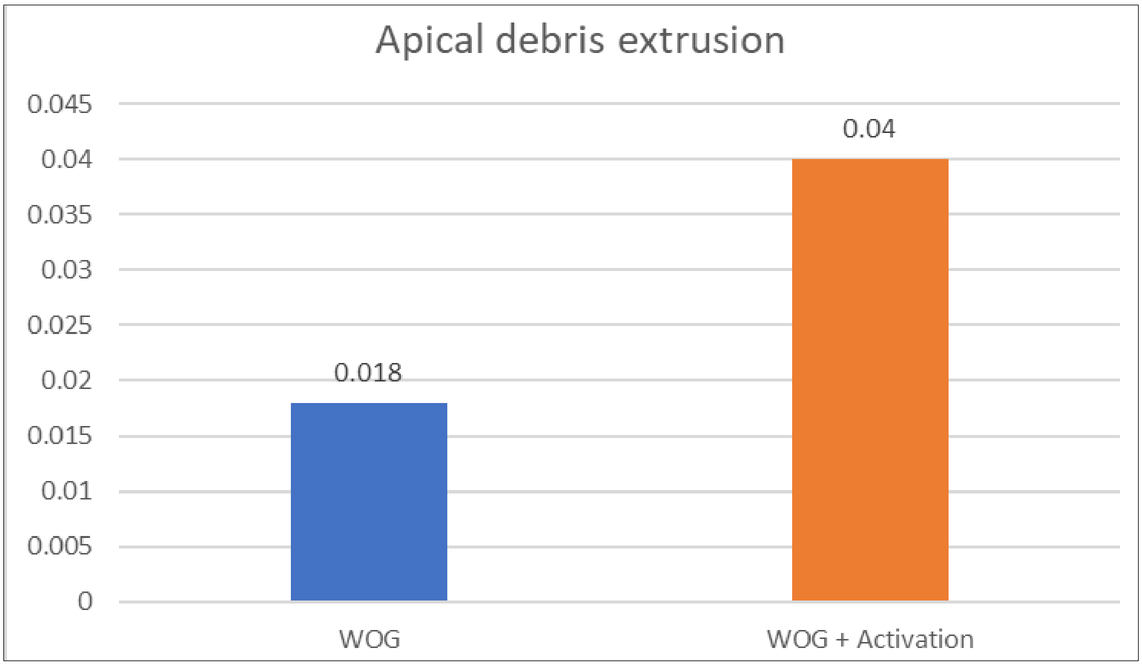
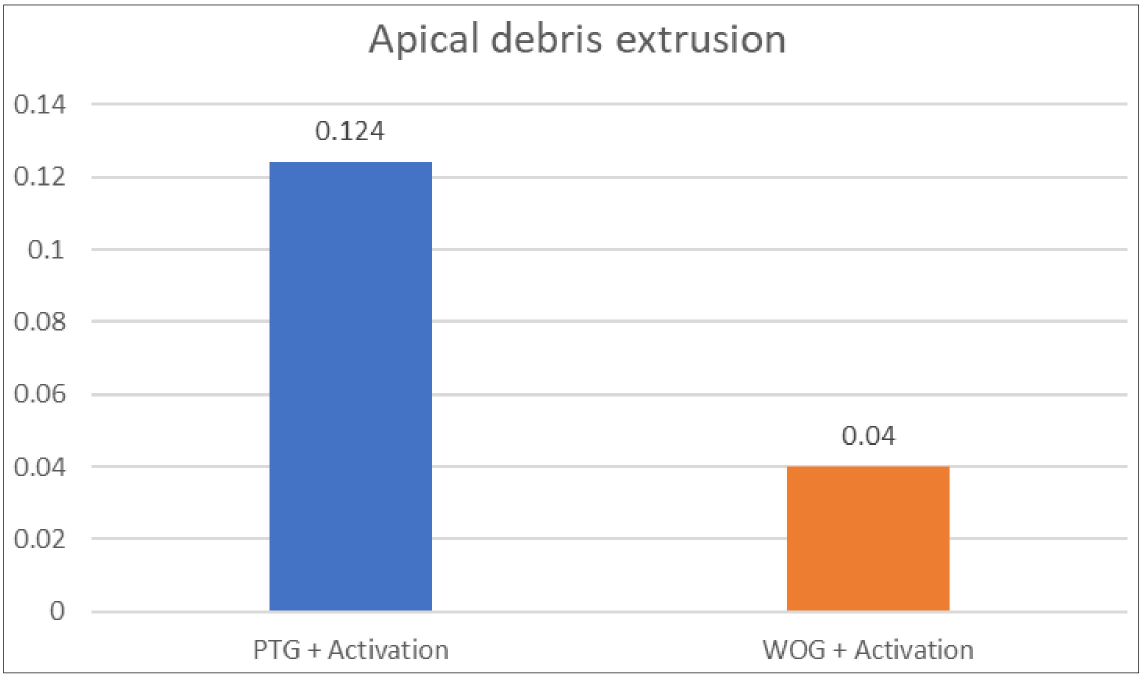


Table 8: Comparison of apical debris extrusion between PTG+Activation and WOG + Activation

	N	Mean	Std. Deviation	Mean Rank	Mann Whitney U value	p value
PTG + Activation	15	.124	.021	23.0	0.000	0.000 HS
WOG + Activation	15	.040	.010	8.0		

Statistical test applied: Mann Whitney U test; HS- Highly significant at p<0.01

The mean value of PTG+activation is significantly very high compared to WOG+activation (p-0.000)



Discussion

The present *in vitro* investigation compared the amount of apically extruded debris produced by ProTaper Gold and WaveOne Gold instrumentation techniques, both with and without sonic activation of irrigants. The findings revealed that ProTaper Gold with sonic activation exhibited the highest level of debris extrusion, followed by WaveOne Gold with sonic activation, while ProTaper Gold and WaveOne Gold without activation demonstrated comparatively lower extrusion levels.

These results highlight two important aspects in endodontic cleaning and shaping: the influence of file design and kinematics on debris extrusion, and the additional role of irrigant activation techniques.

ProTaper Gold is a multi-file rotary system with progressive taper and convex triangular cross-section. Its continuous rotary motion, coupled with multiple files, tends to act in a piston-like manner[3], which may push debris apically, particularly during deeper apical shaping.

In contrast, WaveOne Gold is a single-file reciprocating system with a parallelogram cross-section and off-centred design[4]. Its reciprocating kinematics allow better coronal transportation of debris, thereby generally producing less extrusion compared with full-sequence rotary systems[5]. Previous literature supports that reciprocating systems tend to extrude less debris compared to continuous rotary systems, owing to their debris augering effect toward the coronal direction.

WaveOne Gold and ProTaper Gold differ in taper design and cross-sectional geometry. WaveOne Gold is a reciprocating single-file system with variable tapers (e.g., 25/0.07, 35/0.06, 45/0.05) and a unique off-centred parallelogram cross-section, which reduces dentin contact, minimizes taper lock, and enhances debris clearance[5]. In contrast, ProTaper Gold is a rotary multi-file system with progressive variable tapers distributed across shaping and finishing files, allowing stepwise enlargement and controlled apical sizing. Its convex triangular cross-section offers efficient cutting but engages more dentin surface compared to WaveOne Gold. These design differences make WaveOne Gold more efficient for simplified, single-file shaping, while ProTaper Gold provides greater control and flexibility in staged canal preparation.

Sonic activation of irrigants was associated with an increase in apical extrusion for both systems. This can be attributed to the hydrodynamic agitation generated by sonic activation[6], which enhances irrigant penetration but may also force debris-laden solution through the apical foramen when apical resistance is inadequate. Sonic devices typically operate at lower frequencies than ultrasonic systems but still generate acoustic streaming, which improves debridement in lateral canals and fins[7]. However, in an open apex or when apical constriction is compromised during instrumentation, this activation may inadvertently enhance the risk of irrigant and debris extrusion.

The significantly higher extrusion in the ProTaper Gold group with sonic activation may be explained by the combined effect of multi-file rotary progression and irrigant agitation. The sequential enlargement of the canal by PTG results in more dentin chips and debris generation, and when sonic activation is applied, these loose particles are more likely to be mobilized apically. Conversely, WaveOne Gold generates relatively less debris due to its single-file approach, and although sonic activation still increased extrusion, the overall quantity was lower than that of PTG with activation.

The results emphasize that while irrigant activation techniques enhance canal disinfection, their use must be carefully balanced against the risk of apical extrusion[8]. Clinicians should be aware that activation methods, particularly in systems that already generate more debris, may inadvertently worsen periapical irritation and postoperative pain. This calls for controlled activation strategies, such as avoiding placement of the activation tip too close to the apical third, using lower energy settings, and maintaining sufficient working length control to minimize extrusion.

Irrigant activation plays a crucial role in enhancing root canal disinfection by improving the penetration, flow, and biofilm disruption capacity of irrigating solutions[9]. Sonic activation, in particular, creates acoustic streaming and agitation that significantly increase debris removal and smear layer elimination[10], thereby promoting more effective canal cleanliness and improving the likelihood of endodontic success. However, this vigorous fluid movement can also lead to an undesirable increase in apical debris extrusion, which may cause postoperative pain and periapical inflammation. Thus, while sonic activation is highly effective in optimizing irrigant performance within the canal system, its application must be balanced with careful technique to minimize the risk of extruding debris beyond the apex.

Several studies have shown that reciprocating systems, such as WaveOne Gold, extrude less debris compared to rotary systems like ProTaper Gold[11,12]. Moreover, irrigant activation methods, including sonic and ultrasonic, have been widely reported to enhance smear layer and biofilm removal[13] but also to influence the direction of irrigant flow, potentially increasing apical extrusion under certain conditions. The findings of this *in vitro* study are consistent with these reports, reinforcing the notion that instrumentation design and activation techniques are interdependent variables that directly influence extrusion outcomes.

This study was carried out on mesiobuccal roots of lower molars which probably and the more extruded debris may be because of the smaller diameter of the canal and application of more force during preparation. Increased level of instrumentation difficulty and because the highly variable anatomy and degree of curvature of the root canals in these teeth affect the extrusion of apical debris in this canal.

The irrigation solution is of great importance. Impurities of different irrigants may affect the weight of dry debris and it is known as a confounding factor

In this study, the apical patency was established in all steps. Thus, there was no limit for the extrusion of debris. One of the disadvantages of this apparatus is that it does not mimic the periapical tissues and their back pressures. It has been suggested to simulate the resistance of periapical tissues by using floral

Fig (a)

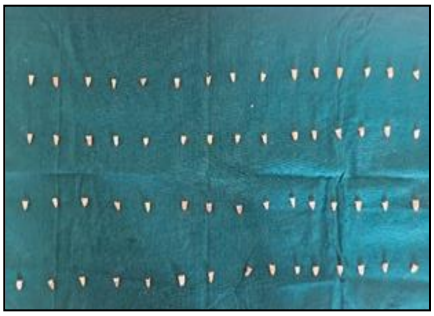


Fig (b)

Fig (c)

Fig (d)

Fig (e)

Fig (f)

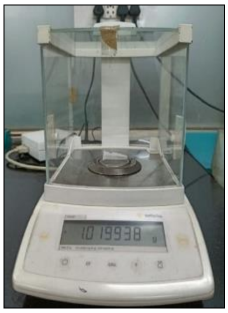


Fig (g)

Fig (A): Armamentarium with endomotor(TriautozxII j.morita),sonic activator (super endo), Electronic apex locator(j.morita mini),hypochlorite, EDTA and Eppendorf tubes, (B): 60 extracted and sectioned mesial roots of mandibular I molar teeth collected C): rotary instrumentation with protaper gold(D): Reciprocation instrumentation with wave one gold (E): sonic activation(F): Eppendorf tube with debris after dried (G):electronic microbalance with 10^{-6}g precision

Conclusions: Based on this study, it was concluded that endodontically treated teeth instrumented with protaper gold rotary instrumentation technique showed highly significant apical debris extrusion compared to wave one gold reciprocation instrumentation technique irrespective of the instrumentation techniques used irrigant activation resulted in increased apical debris extrusion

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