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Apical Extrusion of Debris and Irrigants: An Unavoidable and Inherent Occurrence during Root Canal Treatment: A Literature Review

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Abstract: *Complete biomechanical preparation of the root canal space is one of the most important stage in root canal preparation. Despite strict length control of the endodontic instruments during root canal preparation, the dentinal filings, pulp tissue fragments, necrotic tissue, microorganisms, and the intracanal irrigant may be extruded from the apical foramen into the periradicular region. The apically extruded debris is one of the causes of postoperative flare-ups which can lead to a severe immunological response. A number of studies have confirmed that debris is indeed forced out through the apical foramen during root canal instrumentation. This article presents a comprehensive review on the apically extruded debris which is an unavoidable and inherent occurrence during root canal treatment.*
Keywords: *Apical foramen, biomechanical preparation, debris, irrigants, microorganisms*

I. Introduction

Root canal treatment encompasses thorough cleaning and shaping of the canal. Cleaning is achieved through proper instrumentation and irrigation of the root canal system in addition to creating a suitable shape for complete three- dimensional obturation.

During canal preparation, there may be extrusion of bacteria, dentinal debris, necrotic tissue and irrigants into the periradicular region.[1]The extruded material referred to as the 'worm of necrotic debris' may have the potential to disrupt the balance between microbial aggression and host defence, resulting in incidents of acute inflammation and flare – ups.[2]

Both contaminated and uncontaminated dentin and pulp tissue can trigger an inflammatory reaction when forced periapically during instrumentation.The immunological aspects of postoperative flare-ups demonstrated that antigens originating from root canal resulted in the formation of an antigen-antibody complex when forced beyond the apical foramen, which could lead to a severe inflammatory response.[3]

Chapman etal were the first to verify the expulsion of infective material from the root canal system during instrumentation in 1968.[4] In 1975, VandeVisse and Brilliant showed that instrumentation with irrigation produced significantly more extrusion of debris than instrumentation alone.[5]

Al Omar and Dummer in 1995, revealed that techniques involving a filing with linear motion caused significantly more apical dentin debris than those involving some sort of rotational action.[6]Reddy and Hicks were the first to compare apical debris extrusion between manual instrumentation and engine driven techniques. When comparing the mean weights of apically extruded debris, they noted that the step back technique produced significantly more debris than the engine driven techniques and balanced force technique. Rotary instruments have a tendency to pull dentinal debris into the flutes of the file and direct it toward the coronal aspect of the canal.

It is the common opinion of most authors that the extrusion of some debris is inevitable during root canal instrumentation and a methodology that completely avoids this phenomenon of apical extrusion has not yet been developed. There have been many studies on extrusion of apical debris, which quantitate the debris ,irrigant and bacteria extruded apically by various techniques.

Apical extrusion is not only limited upto extrusion of debris, irrigant or bacteria, but extrusion of obturating materials, intracanal medicaments and root canal instruments also disrupt the integrity of periapical tissues.[7]

This paper will briefly review the relevance of apical extrusion of debris and irrigantsfrom a clinical and biologic perspective.

Why is apical extrusion a concern during root canal treatment?

Extrusion of infected debris to the periradicular tissues during overinstrumentation and irrigation can cause postoperative pain.[8]

In asymptomatic periradicular lesions associated with infected teeth, there is a balance between microbiota and the host. If during chemomechanical preparation microorganisms are extruded into the periradicular tissues, the host is challenged by a larger number of irritants than it was before. Extrusion of debris beyond the apical foramen leads to increased influx of exudates and blood into the root canal which enhances the nutritional supply for the bacteria and exacerbates a chronic lesion.

Consequently, there will be a transient disruption in the balance between aggression and defense, in such a way that an acute inflammatory response ismounted to re-establish equilibrium.

Siqueira documented that the intensity of inflammatory response depends on the number and virulence of the microorganisms extruded from the root canal.[2]

Among different techniques for biomechanical preparation, crown-down technique causes less extrusion of debris than hand- instrumentation so it should be elected as the method of choice for the infected root canals. The amount of extrusion of debris and irrigantsis under the control of the operator upto some extent whereas the microorganisms which are extruded is a factor which is very difficult to control.

If virulent clonal types of pathogenic bacterial species are present in the root canal system and are propelled to the periradicular tissues during overinstrumentation, even a small amount of infected debris will have the potential to cause or exacerbate periradicular inflammation.[9]

Sundqvist in 1992 mentioned that incomplete biomechanical preparation in one visit disrupts the balance of the microbial community. So to avoid flare-ups biomechanical preparation should be completed in the same visit and intracanal medicament should be placed in the root canal in between two subsequent appointments.[10]

How to measure the amount of debris and irrigant extruded? : Various methodologies

To understand the dynamics of apical extrusion of debris and irrigants from the root canal, various in vitro studies have been conducted in which different experimental set – ups simulating the clinical condition have been designed. The most commonly used method in various studies is the one proposed by Myers and Montgomery in 1991.The apparatus consisted of an instrumented root secured with a rubber stopper in glass vial of 15x 45 mm which was placed into a glass flask with a rubber stopper fitted tightly on the mouth of the flask. A 25- gauge needle was placed alongside the stopper during the insertion to equalize the pressure on the inside and outside of the flask. The flask was then held securely in a rubber – jawed vise.

The amount of extruded debris and irrigants is achieved by subtracting the weight of the collection vials after instrumentation and prior to it.To measure the amount of extruded irrigant specifically, the vial with the extruded material was placed next to a caliberated vial with 0.5ml increments of the irrigant used. The dry weight of the irrigants was calculated by placing the vials in a dessicator with $CaCl_2$ crystals.[11]

Other than glass vials, Eppendorf tubes [12]and aluminium crowns suspended beneath the tooth [13]have also been used for the collection of the extruded material.

Another methodologywhich was accepted was given by Ruiz- Hubard et al in 1987.They used acrylic models containing straight and curved canals in which apical wells were prepared.The modelswere cross-sectioned by the apical wells using a diamond saw. After instrumentation, irrigation and drying, the canals were obturated. The debris was then put in a Millipore plastic filter. The moisture was removed by the heat in the oven. The amount of debris extruded was calculated by subtracting the weight of debris and filter from the pre-weighed filter alone.[14]

All the methodologies have both advantages and disadvantages. The use of acrylic models favour the adjustment of the canals according to the desired shape and size. But the models are lagging in natural pulp-tissue and a natural apical constriction.This can lead to false results regarding the amount of debris extruded.

But certain factors which have to be kept in mind for the experimental set –up design which have not yet been considered include sterility of the collection apparatus and the standardization of the apical foramen. Some studies have kept this factor in mind while evaluating the apical extrusion of debris and irrigants.[6, 15, 16]

Also, the use of $CaCl_2$ crystals to evaporate the moisture in order to caliberate the dry weight of the debris does not ensure uniformity in all the samples. The result is subjected to change with the environmental factors.Fairbourn et al in 1987 suggested that a standardized dehydration protocol is must as the moisture from the air can cause an increase in the weight of the debris.[13]

As previously mentioned, the severity of the inflammatory response due to apical extrusion of debris and irrigants depends on quantitative and qualitative factors. The methodologies available till date focus on the quantitative aspect only which is one of the shortcomings of the currently employed techniques.[9]

Some studies have evaluated *ex vivo* that there is extrusion of bacteria during biomechanical preparation.[17,18,19,20]

Enterococcus faecalis is generally selected as the biological marker in these studies. It is a non-fastidious, easy to grow aerobic bacterium. In this test, the root canals are completely filled with *E.Faecalis* suspension by sterile pippetes. Saline is used as an irrigant. The amount of irrigation solution before and after tests is collected and incubated at 37˚ C for 24 hours in brain – heart agar. Results are calculated in CFU (Colony Forming Units).[17]

Although the bacterial extrusion studies are helpful from a clinical point of view, these studies do not take into account the reactions likely to get triggeredwhen sterile fragments are forced into the periapical regions. Also, the virulence characteristics of the bacteria are not evaluated. Additionally, the body defence mechanism cannot be mimicked by a laboratory set – ups.[21]

Furthermore, the periapical tissues act as a barrier to prevent the extrusion of debris. Various techniques are there which have been proposed to simulate the natural condition like the use of floral foam.[22]But the foam may absorb the irrigant and some amount of debris.[23]

Also, Psimma et al in 2012 gave a methodology which incorporated a point conductivity probe to measure irrigant extrusion and a vial system with a valve to adjust pressure and a magnetic stirrer to provide a condition akin to the oral cavity.[24]

With the development of new irrigation devices which create a negative pressure at the apex, the amount of extrusion has reduced significantly.

The variation has led to introduction of newer methodologies to measure the liquid extrusion. Mitchell et al used color change as a parameter in which teeth are embedded in 0.2% agarose gel which changes to purple color as sodium hypochlorite is extruded into the gel. Also the gel fulfils the role of periapical tissue by acting as a barrier.The shortcomings of this methodology are the porous nature of the gel as long as the pH is above 9.[25]

These methodologies are helpful to study the amount of extruded debris and irrigants but the difficulties have to be overcome and an experimental set – up which fulfils all the necessary clinical conditions is yet to be designed.

Summary of various studies on apical extrusion

Many studies have been quoted in the literature which evaluate that various factors are responsible for apical extrusion by instrumentation (hand or rotary), due to apical diameter of the canal, severe canal curvatures and due to various irrigation devices and methodologies.

VandeVisse & Brilliant (1975) were the first to quantify the amount of apically extruded debris during instrumentation.[5] Ruiz – Hubard et al in 1987 showed that instrumentation with an in-and-out motion tended to produce more apically extruded debris than instrumentation with rotational motion.[14] The evaluation of apically extruded debris from different instrumentation techniquesresults in some degree of apical extrusion according to Fairbourn et al. 1987,[13] McKendry 1990,[26] Al-Omari &Dummer 1995.[6]

This proved that cervical flaring and crown – down technique produced less apical extrusion of debris and irrigants.

Reddy & Hicks (1998) were the first to compare apical debris extrusion between hand instrumentation and engine-driven techniques.[7]

While comparing the efficacy of rotary instruments with that of hand instruments, Profile and Protaper have been the most commonly studied rotary instruments. Beeson et al in 1998 compared Profile rotary system with hand K- files and stated that it caused less apical extrusion as compared to hand files.[15]

Tanalp et al. in 2006 compared Protaper, Profile and Hero-Shaper rotary instruments and concluded that Protaper caused more apical extrusion as compared to the other two. They put forward the hypothesis that rotary instruments have a tendency to pull the debris through the flutes out of the root canal in a coronal direction.The reason is the difference in the design of the instrument.[12]

Protaper was also inferior in terms of debris extrusion when compared to K3 in a study by Kustarci et al in 2008[27] whereas Madhusudana et al in 2010[28]reported no significant difference between the same two file systems.

Protaper also extruded more amount of debris when compared to MTwosystem in a study by Tasdemir et al in 2010.[29]

On comparison between Protaper Universal and Protaper Next, Protaper Next produced significantly less amount of debris as proven by Kocak et al in 2015.[30]

Kustarci et al in 2008 also compared K3, RaCe and FlexMaster files with hand instrumentation and concluded that hand instrumentation caused more extrusion of debris and bacteria when compared with these rotary instruments.[27]

Radeva et al in 2014 compared the K3 and RaCe files and concluded that RaCe files extruded comparatively less debris as compared to K3 and the difference was due to the typical instrument design of these files.[31]

When comparisons were made between hand files, sonic and ultrasonic instrumentation, Martin and Cunningham in 1982 suggested that sonic and ultrasonic instrumentation caused less apical extrusion when compared to hand instrumentation. Fairbourn et al in 1987 also supported this hypothesis.[32]

When the effect of apical diameter of the canal on the apical extrusion was taken into account Al-Omari &Dummerin 1995[6]determined that there was no corelation between the two. Hinrichs et al in 1998 [16]also supported the findings of this study.

On the other hand, Tinaz et al in 2005 hypothesised that greater amount of apical extrusion of debris occurred when there is an increase in the apical diameter.[33]

Canal curvatures do not significantly cause greater amount of apical extrusion as proved by Leonardi et al in 2007. In this study, canals with curvatures greater than 5 – 10 degrees were used.[34]

Brown et al in 1995 stated that the use of a reservoir for irrigation in the coronal access cavity and passive insertion of needle provide a safer treatment procedure and decrease the likelihood of apical extrusion of the irrigant.[35]

When a comparative evaluation is done regarding the types of needles used for irrigation and the amount of irrigant extruded, studies have proved that side – vented needles cause lesser amount of extrusion as compared to regular needles. This has been supported in a study by Altundasar et al in 2011.[23] The inefficient cleaning of the apical third by tip – vented needles has also been proven in a study by Boutsakis et al in 2009.[36] Mittal et al in 2015 compared the apical extrusion of debris and irrigants by different irrigating needles (Tip vented, side- vented and ultrasonic tips). They concluded that ultrasonic tips caused the least extrusion of debris.[37] To overcome the problem of apical extrusion of irrigant, manual dynamic irrigation which uses a gutta- percha cone in short gentle strokes to activate the irrigant hydrodynamically was advocated by McGill et al in 2008.[38]Another way was the use of a negative pressure irrigation device called EndoVac (Discus Dental USA). The better results of EndoVac were supported by various studies by Desai et al in 2009,[39] Mitchell et al in 2010,[25] 2011[40]and Gondim et al in 2010.[41]

Methods to prevent apical extrusion of debris and irrigants

All instrumentation techniques produced debris and irrigant extrusion apically. The engine driven Ni-Ti systems extruded significantly less apical debris than hand instrumentation technique. None of the instrumentation techniques can clean the apical third completely and average remaining debris score was high in hand instrumentation. Lastly, EndoVac system seems to be the device to safely deliver irrigant to working length and suctions out fluid and debris from as far as the actual apical terminus. Hence, in the present scenario, all instrumentation should focus on the elimination of debris and bacteria that especially cause flare-ups, but it is not only the quantity of debris the type and virulence of the bacteria it contains that is also responsible for acute exacerbation.

II. Conclusion

Microbial injury caused by microrganisms and their products that egress from the root canal system to the periradicular tissues is conceivably the major and the most common cause of inter-appointment flare-ups. All preparation techniques and instruments have been reported to be associated with extrusion of infected debris, even when preparation is maintained short of the apical terminus. However, engine-driven nickel titanium instruments extruded less bacteria than a manual technique..Thus, with the combined use of crown – down technique and negative pressure irrigation, the operator can minimize the flare – ups by reducing the common error of apical extrusion of debris and irrigants.

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