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A novel approach to construction and working of fluid filtration model: An experimental study

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Abstract

Aim: The aim of the study was to construct a novel fluid filtration model and analyse the working of the model for the quantitative evaluation of microleakage. **Materials and Methods:** An oxygen cylinder equipped with pressure adjusting device was connected to a pressurised buffer system, which was then connected to micropipette and a three-way control faucet, the faucet holds attachment for syringe at the upper portion and the tooth sample at the lower part. A tooth sample with perforation condensed with Gutta percha and without perforation was connected to the fluid filtration model, to ensure bubble displacement a bubble was introduced in micropipette. A digital SLR camera was used to record the bubble displacement, AutoCAD Software for the measurement and custom made software for calculation of microleakage. **Results:** The model was constructed and functioned successfully. **Conclusion:** This model can be used for the evaluation of microleakage of dental materials.

Keywords: Novel fluid filtration, Working of fluid filtration, Software based analytical study.

INTRODUCTION

The most desirable property of any restorative material is that it should have a complete and long lasting seal at the margins that prevents any fluid movement thereby making an entry of microorganisms beneath the restoration. The tooth restoration interface is an area of clinical concern and critical as far as microleakage is concerned.

A microscopic space always exists between the tooth restoration interface leading to passage that allows the percolation of oral fluids and microorganism's thus causing microleakage that may jeopardize the clinical longevity of restoration [1-4]. Clinically, microleakage results into postoperative sensitivity, secondary caries, pulpal pathology and marginal staining [5]. Marginal staining will further cause marginal breakdown, consequently allowing the penetration of microorganisms, multiplication of these organisms and subsequently diffusion of the microorganisms and their toxic products into the dentinal tubules causing pulpal inflammation. Despite of advances in various restorative materials ,placement techniques and curing strategies microleakage still exists causing restorative failure, further emphasising that measuring microleakage is an important aspect.

There are various methods to measure microleakage including chemical, bacterial and radioactive tracers, dye penetration, dye extraction, electrochemical, neutron activation, micro-computed tomography, however they present inherent drawbacks [6].

The fluid filtration method developed by Pashley *et al* has been widely used to measure microleakage [1]. This method has several advantages over the commonly used methods: the samples are not destroyed, permits the evaluation of microleakage over time, operators bias and most importantly the results are accurate since very small volume is recorded [1-4].

The purpose of this study was to construct and analyse the working of the novel fluid filtration system and assist the researchers to construct a simpler and more feasible model to study micro leakage.

MATERIALS AND METHODS

The system involves the assessment of fluid movement in the model calculated through bubble displacement [4]. It is essential to apply pressure to fluid for the displacement of bubble. An oxygen cylinder equipped with a pressure adjusting device was utilised. A specific latex plastic tube was connected to oxygen source and the end part being connected to the pressurised buffer system (Borosil co.) Two openings were created on the cap of pressurised buffer system, one for the entrance of oxygen and other for the discharge of the fluid. The tube which transports oxygen was placed above the fluid level, the other glass tube was entirely engrossed in liquid. The glass tube that discharges the fluid was connected to micropipette (0.1cc). Micropipette (Borosil co.) was horizontally fixed on a 5 mm thick foam core board with a support of fabricated frame. The other side of micropipette was connected to a three way bilateral control faucet (2 mm bore). The control faucet connects two openings at a time. The upper part of three way control faucet was connected to a syringe, which was used to create an air bubble inside the micropipette. The size of air bubble was kept equal to the internal diameter of micropipette so as to ensure a precise movement .The lower part was connected to the tooth sample (dentin disc). The connections were coated with cynoacrylate adhesive (pidillite co.).

The system as shown in the Figure 1 and Figure 2 consists of two sections:

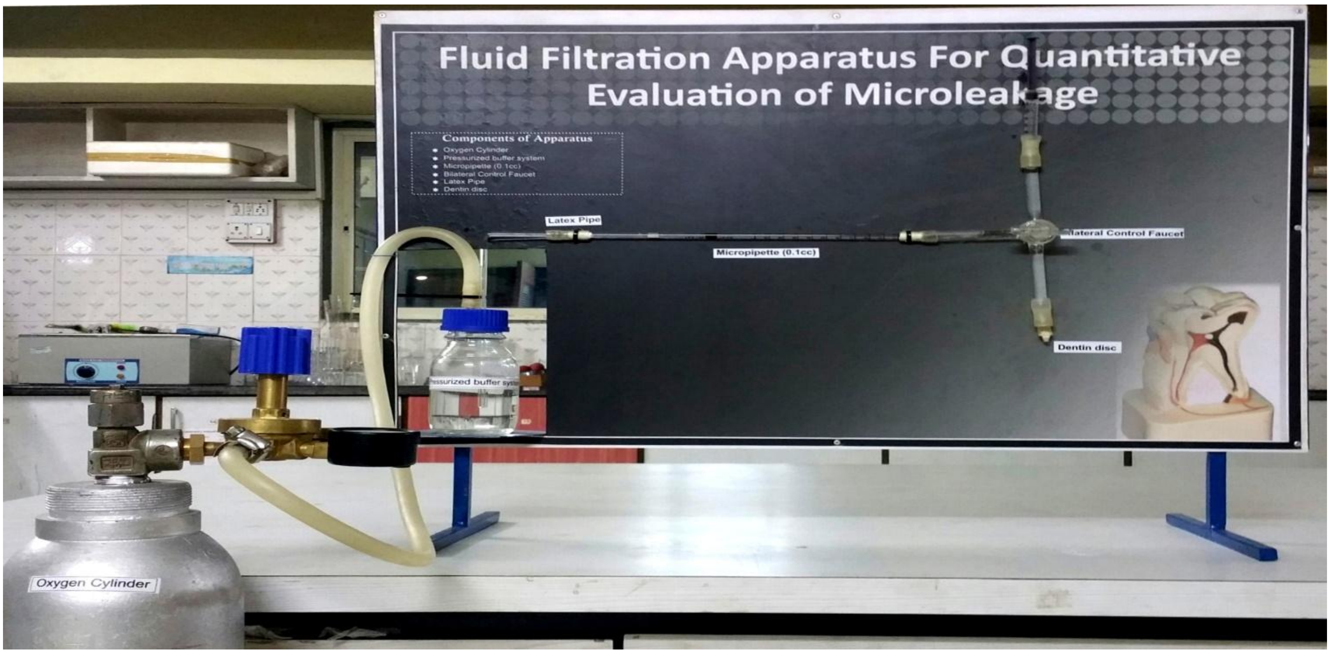

Figure 1: SECTION A –From left to right oxygen cylinder, pressurized buffer system, latex pipe, micropipette, three way bilateral control faucet, syringe and tooth sample

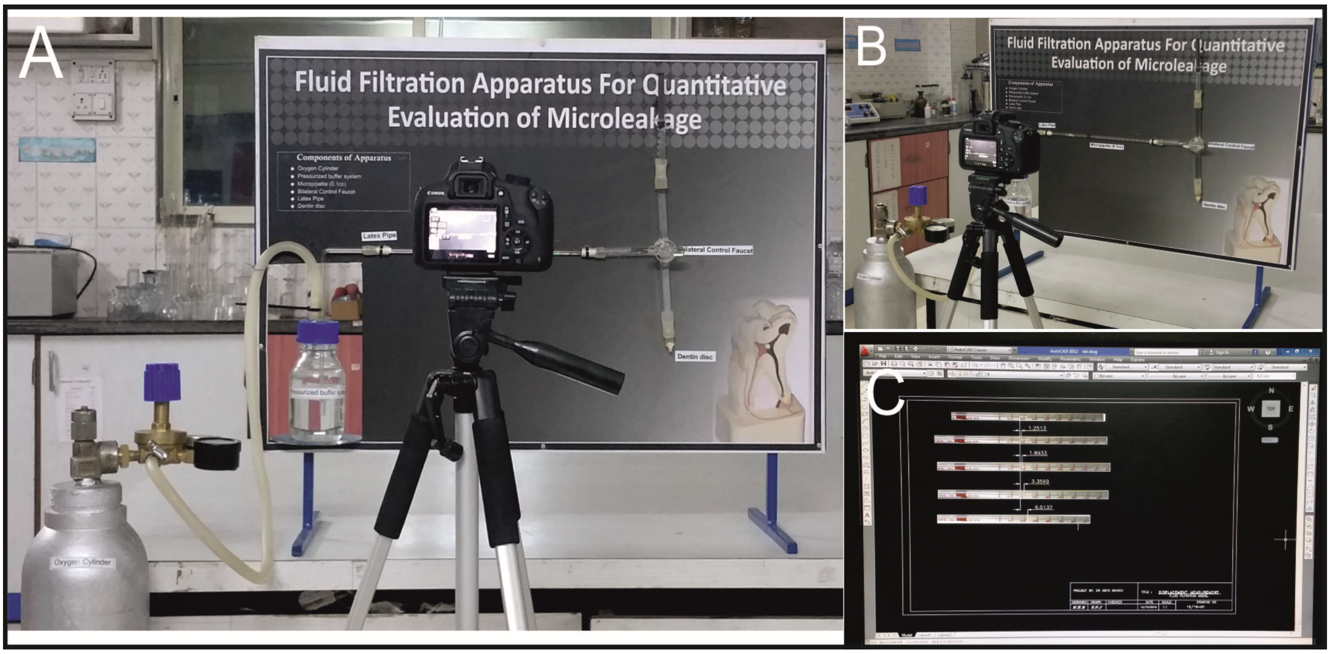

Figure 2: SECTION B (Recorder of the system) A- fluid filtration model with digital SLR camera. B- Lateral view. C- AutoCAD system (amount of bubble displacement)

SECTION A: Consists of the tubes, pipes, syringes, micropipette, control faucet, buffer system (Borosil co.) and the tooth sample

SECTION B: Consists of the recorder of the bubble displacement which includes digital SLR camera (Canon1200D) AutoCAD (Autodesk, Inc.)

The distance from the micropipette was the closest possible to allow the digital SLR camera to cover the entire range of the bubble movement. In this study, we considered a positive and a negative control sample.

The positive sample was a dentin disc with a perforation condensed with Gutta percha to ensure that the fluid displacement takes place. The negative control sample was an intact disc.

Firstly, the Negative tooth sample was connected to the three way control faucet; the control faucet was closed towards the tooth sample so that only micropipette and syringe were connected. A bubble was created in the micropipette using a syringe. After the insertion of bubble in the micropipette, the control faucet was closed towards the syringe ensuring the connection of micropipette to the tooth sample. Simultaneously, the digital SLR camera was adjusted. Gradually, the oxygen was released from the oxygen cylinder with the help of pressure adjusting device which was adjusted at 4 to 6 psi. The first image of bubble movement was taken after 2 minutes subsequently images were taken after 4 minutes, 6 minutes and 8 minutes. The same steps were repeated for the positive control sample.

An AutoCAD 2012 and custom made software for calculation of bubble displacement were designed. The images of bubble movement were transferred to AutoCAD. The custom made software calculated the mean displacement of the bubble per minute per cm of H_2O. The amount of microleakage was presented in μL/min/cm H_2O.

RESULTS AND DISCUSSION

No bubble movement was observed in negative control sample, but in the positive control sample bubble movement was observed which was calculated as 7.40193×10^{-7} lit .i.e. 0.74μL/min/cm H_2O.

The purpose of the study was to construct a novel fluid filtration system, which can be efficiently used for quantitative evaluation of microleakage [4]. Through years a variety of microleakage assessment methods have been introduced and studied, however all these methods give the qualitative analysis, the clear conclusion on the appropriateness of various leakage studies remain elusive and they lack scientific significance [7,8].

In this study, we have used oxygen gas pressure since it was more feasible; a nitrogen or helium gas can also be used [3]. The pressure was kept constant throughout the experiment. The applied pressure was 4 to 6 psi; although there is no specific value to what the pressure has to be applied. Wimonchit *et al* used a pressure of 100mm Hg, Pommel *et al* used 15 cm H_2O, Bobotics *et al* used a pressure of 20 psi for evaluation of microleakage in temporary restorations. A study on unpredictability of seal after post space preparation done by Abvamovitz in which he utilised a pressure of 1.2 atmosphere. Robert and Pashley used a pressure of 3 to 4 psi to study the coronal microleakage of materials used to create intracoronal seal. The amount of pressure used largely depends on the materials used in the study and the amount of pressure they can withstand, all the materials in this study could withstand a pressure from 4 to 6 psi. The applied pressure also varies according to the design of the model and the various published protocols [2].

Initially an Erlens flask (Borosil Co.) with two openings was utilised however at about 2 psi pressure it exhibited leakage. A conical flask (Borosil Co.) with thick glass was used, to which a rubber cork with two openings were attached and tightly sealed with cynoacrylate adhesive however this attachment did not resist the pressure for a long time. Hence a Pressurised buffer system (Borosil Co.) with thick glass and a special ‘O’ ring at the cap was utilised for the study which provided no leakage even at high pressure for a long duration.

A micropipette of 0.1cc (Borosil Co.) was used in this study; the reason behind using a small diameter was the fact that the smaller the diameter, the more accurate is the measurement. A bubble of the same size of the internal diameter of the micropipette was introduced. For instance a large bubble may compress more than a small bubble or many small bubbles may compress to form a single large bubble.

When the samples are connected to system under pressure it is important to consider the compliance, bubble compression, tube expansion and existing voids. Hence, the fluid under pressure is allowed to reach a steady state for which it takes ½ minute, later the movement of bubble can be recorded. Wu et al calculated a theoretical time of 50 seconds for the stability of the system [10]. The air bubble in the micropipette may move continuously, and a small measurement time may lead to false results. The measurement time should be generally between a range of 1 min to 3 hours [1]. In the current study, the measurement time was 2 minutes, 4 minutes, 6 minutes and 8 minutes considering the positive sample with perforation condensed with Gutta percha, which was used to evaluate the working of the system. The measurement time should be as long as possible to increase the accuracy. Wu et al calculated used a measurement time of 3 hours [10].

Various researchers have studied the fluid filtration system. Robert and Pashley 2002 studied coronal microleakage of five restorative materials used to create intracoronal seal in endodontically treated teeth. Pashley *et al* in 1994 studied the permeability and microleakage of Class II resin composite restorations and concluded fluid filtration as one of the ideal method to evaluate microleakage [3]. Howard *et al* 2001 used fluid filtration method in studying the microleakage of root end filling material and concluded as an excellent method to screen root end filling materials [6].

Dye penetration is a common technique and has gained popularity because of ease in use and relative low cost; however the most important is the small size of dye molecule that probably gives over estimation of results. Hashem and Hassanien 2008 studied the correlation between dye penetration and presence of periapical pathosis which were determined radiographically, however the results of dye penetration did not correlate with the quality of root canal filling as judged by radiograph [2]. Oliver and Abott (2001) studied the clinical relevance of dye penetration method and concluded that the results were not relevant from a clinical point of view [2,4]. Susini *et al* (2005) studied the microleakage using dye extraction and concluded this method more relevant to dye penetration but lack in accuracy as compared to standard methods like fluid filtration [12]. Author compared dye penetration, dye extraction and fluid filtration method and concluded dye extraction and fluid filtration equally effective in assessment of leakage [9].

Torabinejad *et al* studied coronal microleakage of endodontically treated teeth using a bacterial penetration model however concluded that the study was static and could not simulate clinical conditions [10]. Mortenson *et al* and Krakow *et al* (2015) quoted bacterial penetration model more clinically and biologically relevant but the method as more time consuming, more complex and requires a skilled microbiologist [13].

All the above mentioned techniques are two dimensional in nature; over the past few years there have been efforts to investigate microleakage three dimensionally. One of the most advanced technique in recent years has been the advent of micro-computed tomography (MCT) that can achieve a spatial resolution at micron level, The MCT skyscan 1072 along with its advantages presented certain drawbacks: the samples were destructed, the method could not reflect clinical situation 50% silver nitrate solution which was used in the study was not bufferised and caused marginal erosion leading to confounding results.

Thus, no material in the literature provides leak proof seal, even if there is no gap between the material and tooth the bacteria's may diffuse through microchannel within the smear layer. Hence, it is advisable to measure microleakage with such a method that allows the detection of micro voids along with the preservation of samples, though fluid filtration method is technique sensitive, it is considered to be one of the ideal method for assessment of microleakage.

CONCLUSION

Microleakage is definitely an important issue in modern dentistry, particularly when adhesive restorations are at pace. This novel fluid filtration model with more simplified construction and elaboration of method of working will definitely help researchers to construct and study microleakage and eliminate the unreliable methods used for testing leakage.

There are wide range of variations in the amount of applied pressure, the size of bubble, measurement time and the materials used by various researchers and hence a need to better standardisation is required.

No conflict of interest: Nil

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