Effect of different instrument systems on the quality of bio-ceramic obturation material (An in vitro leakage and SEM Study)

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Background and Objectives: Bioceramic-based root canal sealers need more evidence for proving its sealing ability. The objective of this in vitro study is to measure the leakage of extracted root canals and analyze the interfacial adaptation of the bioceramic material to canal walls.

Methods: 60 extracted human lower mandibular teeth were divided randomly into 6 groups (each group 10 teeth). Group 1 and 4 were instrumented by protaper next rotary files, group 2 and 5 by wave one reciprocating files and group 3 and 6 by Two shape rotary files. All of the specimens were obturated with thermal (warm vertical compaction) technique using bioceramic as sealer. The leakage of specimens of group 1, 2 and 3 was evaluated by dye penetration method. The interfacial adaptation of specimens of group 3, 4 and 5 were analyzed using scaning electron microscopy.

Results: statistics for groups 1, 2 and 3 revealed that Wave one group showed the best leakage (mean of 0.7 mm) with significant difference. By using ANOVA; Post hoc LSD test revealed that difference between groups 1 and 3 was significant, while differences between groups 2 and 1 and between groups 2 and 3 were non-significant ($p<0.05$).

The descriptive statistics for groups 4, 5 and 6 revealed that Two shape file group showed the least interfacial gap width (mean-=31.2 µm). By using ANOVA; Post hoc LSD test revealed that difference between groups 4 and 5 was non-significant, while difference between groups 4 and 6 plus 5 and 6 were significant ($p<0.05$).

Conclusion: Different instrumentation systems had effect on the obturation quality of bioceramic material.

Keywords: Bioceramic sealer, apical leakage, interfacial adaptation.

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Introduction

Root canal therapy depends on integrally related root canal treatment phases: microbial control, cleaning and shaping, and effective sealing of the root canal system. The success of each depends on the perfection of the final phase.[1]

Ideally, the root canal sealer should be capable of performing an effective bond between the core material and the root canal dentin thus preventing leakage. It should also be non-toxic and preferably have a positive effect on the healing of periapicalarea.[2]

Bioceramics are materials designed for use in medicine and dentistry. They include alumina and zirconia, bioactive glass, glass ceramics, coatings and composites, hydroxyapatite andresorbable calcium phosphates.[3,4]

Bioceramics are exceedingly biocompatible (nontoxic) and they are chemically stable within the biological environment. Also, bioceramics do not shrink upon setting. In fact, they actually expand slightly upon completion of the setting process. Furthermore bioceramics will not result in a significant inflammatory response if overfill occurs during the obturation process or in a root repair. These are all high standard properties for any sealer. A further advantage of the material itself is its ability (during the setting process) to form hydroxyapatite and ultimately establish a chemical bond between dentin and the appropriate filling materials. Some of the advantages of bioceramic material are: high pH (12.8) during the initial 24 hours of the setting process (which is strongly antibacterial); hydrophilic nature, enhanced biocompatibility, does not shrink, does not resorb (which is critical for a sealer-based technique), excellent sealing ability, sets quickly (3 to 4 hours) and its ease of use (particle size is so small it can be used in a syringe).[5]

In addition to its excellent physical properties, the purpose of bioceramic sealer is to improve the convenience and delivery method of an excellent root canal sealer while simultaneously taking advantage of its bioactive characteristics (it utilizes the water inherent in the dentinal tubules to drive the hydration reaction of the material, thereby shortening the setting time). The dentin is composed of approximately 20% (by volume) water; and that water initiates the setting of the material and ultimately results in the formation of hydroxyapatite. Therefore, if any residual moisture remains in the canal after drying, it will not adversely affect the seal established by the bioceramic cement. This is very important in obturation and is a major improvement over previous sealers. Furthermore, its hydrophilicity, small particle size, and chemical bonding to the canals' walls make it excellent in hydraulics point of view.[6]

Another aspect to sealer hydraulics is that the shape of the prepared canal itself. Actually, it all begins with the specific preparation created by the file; a constant taper preparation. When using the EndoSequence technique as example, it can create either a 0.04 constant taper preparation or a 0.06 taper. The real key is the constant taper preparation, because when accomplished it now gives us the ability to create predictable, reproducible shapes. A variable taper preparation is not recommended because its lack of shaping predictability. This lack of endodontic synchronicity is why all variable taper preparations are associated with the overly expensive and more time consuming thermoplastic techniques. Knowing in advance what the final shape (constant taper preparation) will be is a tremendous advantage in creating superior hydraulics (true endodontic synchronicity). This concept of having everything match is so important because it allows us, for the first time, to perform rotary endodontics in a truly conservative fashion and to be able to use a hydraulic condensation technique. Furthermore, when used in conjunction with the bioceramic filling system, this becomes a synchronized hydraulic condensation technique.[7]

Since the preparation might have a tremendous effect on the quality of the bioceramic material obturation and due to little information through literature about this aspect, this in vitro leakage and SEM study had been conducted.

Materials and methods

Sample preparation. A total of sixty extracted human lower mandibular teeth of single straight canals had been used for this study. Crowns of them had been removed leaving 12.0 mm of root length by diamond disc. File no.15 (K-file) had been inserted in the canal until it had been visible at the apical foramen to check the patency. The root canals with different working lengths had been prepared using:

1. ProTaper Next Rotary System to size X2 corresponding to 25/06, according to the manufacturer's instructions at 300 rpm and a torque of 4.0 Ncm. Instruments had been discarded after preparing two canals. Irrigation with 2 mL of 5.25% sodium hypochloride solution had been performed during rotary preparation.
2. WaveOne Gold Receprocation System (Primary size) corresponding to 25/07,

according to the manufacturer's instructions at reciprocating program. Instruments had been discarded after preparing two canals. Irrigation with 2 mL of 5.25% sodium hypochloride solution had been performed during reciprocation.

3. Two Shape Single File Rotary System (Shape File) corresponding to 25/06, according to the manufacturer's instructions at 350 rpm and a torque of 2.5 Ncm. Instruments had been discarded after preparing two canals. Irrigation with 2 mL of 5.25% sodium hypochloride solution had been performed during rotary preparation.

Sample grouping. Specimens had been randomly divided into 6 groups (n=10) based on simulated canal preparation type and mode of evaluation:

1. ProTaper Next System-Leakage model;
2. WaveOne System-Leakage model;
3. Two Shape System-Leakage model;
4. ProTaper Next System-SEM interfacial gap analysis;
5. WaveOne System-SEM interfacial gap analysis; and
6. Two Shape System--SEM interfacial gap analysis.

Extracted tooth root canal preparation. The working length was obtained by measuring the length of the initial instrument no.15 ISO K-file which was just seen by naked eye at the apical foramen minus 0.5 mm. The measured working lengths were recorded on each sample. The total amount of irrigant solution was standardized for all groups with 10 ml of 5.25% sodium hypochloride. The irrigation needles were inserted into two thirds of the root canals without binding.[8]

Traditional lubricant soup was put inside the canal each time before rotary instrumentation. The rotary instruments were used to enlarge two canals only and were replaced by new instruments. The flutes of the instruments were cleaned with ethyl alcohol and dried after each use.[8]

The specimens in group 1 and group 4 were instrumented and prepared as follows: The rotational direction of the ProTaper was forward (clockwise) continuous rotation. The rotational speed was 300 rpm and the torque limit value was 4.0 Ncm, These operating programs were displayed on the X -SMATR PLUS motor as they were set by the manufacturing company.

Before starting instrumentation reproducible glide path (RGP) was ensured by no.15 ISO K-file which was smoothly inserted and removed from the canal. The instrumentation started with X1 shaping file up to two thirds of the canal for twelve seconds in a gentle in and out pecking motion with brushing technique according to manufacturing instructions, after that; the file became loose and was removed from the canal, and then one ml sodium hypochloride irrigation was performed. After irrigation; the RGP was checked with #15 K-file.

After that the setting program of X-SMATR PLUS was manipulated from the ProTaper setting into the Pathfile setting. The Pathfile no. 16 was used up to full working length of the canal for five seconds for canal patency, the Pathfile was used in a gentle in and out motion, then 0.5 ml sodium hypochlorite.

The next file was the X2 shaping file which was used up to two thirds of the canal for twelve seconds in a gentle in and out motion with brushing technique according to manufacturing instructions, after the timed instrumentation the file became loose and was removed from the canal, then 1 ml sodium hypochlorite irrigation. After irrigation RGP was checked with #15 K-file. The Pathfile no. 16 was used again for five seconds up to full working length of the canal, then 0.5 ml sodium hypochlorite irrigation.

The X1 shaping file instrumentation was used again but this time up to full working length of the canal for twelve seconds, then 1 ml sodium hypochlorite irrigation. After irrigation RGP was checked with #15 K-file. After that the Pathfile no. 16 for 5 seconds up to full working-length of the canal, then 0.5 ml sodium hypochlorite.

Then X2 shaping file was used again but up to full working length of the canal for twelve seconds, then 1 ml sodium hypo chloride irrigation was done. After irrigation RGP was checked with #15 K-file. Again Pathfile no. 16 was used for five seconds up to full working length of the canal, and then 0.5 ml sodium hypo chloride irrigation was

done.

After finishing the steps of instrumentation and irrigation, Size 25 k-file was inserted up to full working length to check that instrumentation was completed. Total instrumentation time was seventy nine seconds. Total irrigation amount was 10 ml.

The specimens of group 2 and group 5 were instrumented and prepared as follows: The rotational direction of the Wave-One was reciprocation motion. The rotational speed and the torque limit value were not displayed on the screen. Before starting instrumentation reproducible glide path (RGP) was ensured with K-15 file which was smoothly inserted and removed from the canal.

The instrumentation started with Primary wave one file up to one third of the canal for twelve seconds in a gentle in and out pecking motion with brushing technique according to manufacturing instructions, after the timed instrumentation the file became loose and was removed from the canal, then 1 ml sodium hypo chloride irrigation.

After irrigation RGP was checked with k-15 file. After that Pathfile no. 16 was used for five seconds up to full working length of the canal, and then 0.5 ml sodium hypochloride irrigation was done. Again Primary wave one file instrumentation was done but this time up to two thirds of the canal for twelve seconds then 1 ml sodium hypo chloride irrigation was done. After irrigation RGP was checked with k-15 file.

After that the Pathfile no. 16 was used for five seconds up to full working length of the canal, and then 0.5 ml sodium hypo chloride irrigation was done. After that Primary wave one file instrumentation was done up to full working length of the canal for twelve seconds then 1 ml sodium hypo chloride irrigation was done. After irrigation RGP was checked with k-15 file then final irrigation was done with 5.5 ml with sodium hypo chloride.

After finishing the steps of instrumentation and irrigation, size 25 k-file was used inserted up to full working length to check that instrumentation was completed. Total instrumentation time was forty six seconds. Total irrigation amount was 10 ml.

The specimens of group 3 and group 6 were prepared and instrumented as follows: The rotational speed was 350rpm and the torque limit value was 2.5 Ncm. Before starting instrumentation reproducible glide path (RGP) was ensured with K-15 file which was smoothly inserted and removed from the canal,

The instrumentation started with finishing file up to one third of the canal for twelve seconds in a gentle in and out pecking motion with brushing technique according to manufacturing instructions, after the timed instrumentation the file became loose and was removed from the canal, then 1 ml sodium hypo chloride irrigation. After irrigation RGP was checked with k-15 file. After that Pathfile no. 16 was used for five seconds up to full working length of the canal, and then 0.5 ml sodium hypo chloride irrigation was done. Again the file instrumentation was done but this time up to two thirds of the canal for twelve seconds then 1 ml sodium hypo chloride irrigation was done. After irrigation RGP was checked with k-15 file.

After that the Pathfile no. 16 was used for five seconds up to full working length of the canal, and then 0.5 ml sodium hypo chloride irrigation was done. After that the file instrumentation was done up to full working length of the canal for twelve seconds then 1 ml sodium hypo chloride irrigation was done, After irrigation RGP was checked with k-15 file then final irrigation was done with 5.5 ml with sodium hypo chloride.

After finishing the steps of instrumentation and irrigation, Size 25 k-file was used inserted up to full working length to check that instrumentation was completed. Total instrumentation time was forty six seconds while the total irrigation amount was 10 ml. After instrumentation all prepared and instrumented roots were place in distalled water in different bottles (6 bottles for 6 groups).

Extracted tooth root canal obturation. The roots of each group were obturated with gutta-percha of the corresponding company of the instruments that were used to instrumentation. The thermal (warm vertical compaction) technique was used. After injecting bioceramic sealer single cone was applied and cut by 5mm. then injectable

gutta-percha was used with compaction, after that injecting gutta-percha with compaction.

The access cavities would be temporarily sealed (Cavit-G), and the specimens had been then stored in a humidified chamber (100% humidity and 37°C) for 2 weeks to allow the sealers to set. To reduce inter-operator variability, a single operator had been carried out all the specimens' instrumentation and the obturation procedure.

Dye penetration. After obturation Group1, 2and 3 specimens were kept in gauzes wetted with distalled water for 72 hours. The apical 2 mm of each sample was measured with caliper and marked, then the rest of root surface was painted with 3 layer of nail varnish(one layer applied and wait for drying and apply next layers withthe same procedure). The nail varnish applied to all surfaces of the roots except for marked apical 2 mm in such a way for dye to penetrate only from apical area.

After that every 5 roots were placed in prepared Rhodamin B solution for 72 hours. During this period of time; each bottle were shaken for every 8 hours to allow every surface to be in contact with the solution.[8]

Clearing. After this period every specimens was removed from dye solution and washed under tap water and the nail varnish was removed and the specimens were placed in prepared 5% nitric acid. End point of decalcification was determined by taking radiograph. In this point dehydration was begin by putting the specimens in arrangement with ascending grades (80%, 90%, 95% and 100%) Isopropyl alcohol. At last specimens were immersed in methyl salicylate for at least 3 hours to make them transparent (the obturation material could be seen by naked eye). The specimens were stored in the solution until the time that they were examined by stereomicroscope.

Scanning electron microscope. The specimens of Group 4, 5 and 6 were prepared to be scanned by electron microscope with different magnifications ranged from 200x-1000x. After obturation; the roots of these groups were cut and sectioned to 3 coronal, middle and apical parts. The roots were measured by caliper and marked. Then cut by diamond discs using angle hand piece with water supply. Then the sections kept in gauzes wet by distilled water. Then the sections were ready to be scanned with electron microscope.

Results

The descriptive statistics for groups 1, 2 and 3 were examined in Table 1.1. Wave one group showed the least leakage result with mean of 0.7 mm. By using ANOVA; there was highly significant difference between the groups. Post hoc LSD test was used to reveal where is the significance between each pair of groups, non-significant difference was between groups 1 and 3, while significant difference were present between groups 2 and 1 plus 2 and 3 ($p<0.05$). Tables 1.2 and 1.3 show the inferential statistics.

The descriptive statistics for groups 4, 5 and 6 were examined in table 1.4.Two shape file group showed the leastinterfacial gap width with mean of 31.2µm. By using ANOVA; there was highly significant difference between the groups. Post hoc LSD test was used to reveal where is the significance between each pair of groups, non-significant difference was between groups 4 and 5, while significant difference were present between groups 4 and 6 plus 5 and 6 ($p<0.05$). Tables 1.5 and 1.6 show the inferential statistics. Figures 1.1 and 1.2 show the difference between groups.

Table 1: Descriptive Statistics for leakage groups.

Descriptive Statistics							
	N	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
G1	9	0.001	7.00	1.1111	0.75359	2.26078	5.111
G2	9	0.001	2.00	0.6667	0.28868	0.86603	0.750
G3	9	0.001	4.00	1.0000	0.44096	1.32288	1.750

Table 2: ANOVA test for leakage groups.

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	38.167	27	12.722	38.167	0.002
	Within Groups	1.333	2	0.333		
	Total	39.500	29			

Table 3: Post hoc LSD test for leakage groups.

LSD		
Dependent Variables	G2	G3
G1	0.031	0.963
G3	0.026	

Table 4: Descriptive Statistics for SEM groups.

Descriptive Statistics							
	N	Minimum	Maximum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
G4	30	2.50	129.00	37.2457	5.73531	31.41359	986.814
G5	30	2.80	247.00	38.5183	10.59134	58.01113	3.365E3
G6	30	2.00	222.00	31.2240	8.85604	48.50651	2.353E3

Table 5: ANOVA test for SEM groups.

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
	Between Groups	97558.649	26	3752.256	323.375	0.000
	Within Groups	34.810	3	11.603		
	Total	97593.459	29			

Table 6: Post hoc LSD test for SEM groups.

LSD		
Dependent Variables	G5	G6
G4	0.561	0.023
G6	0.035	

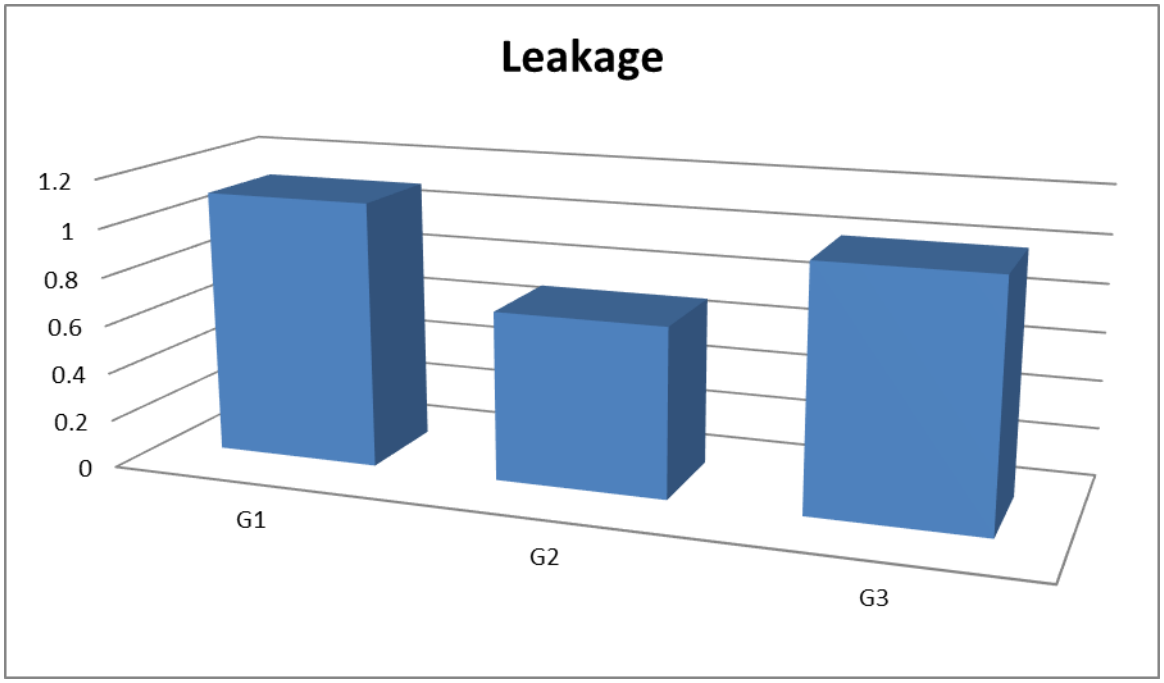

Figure 1: Difference between groups for leakage.

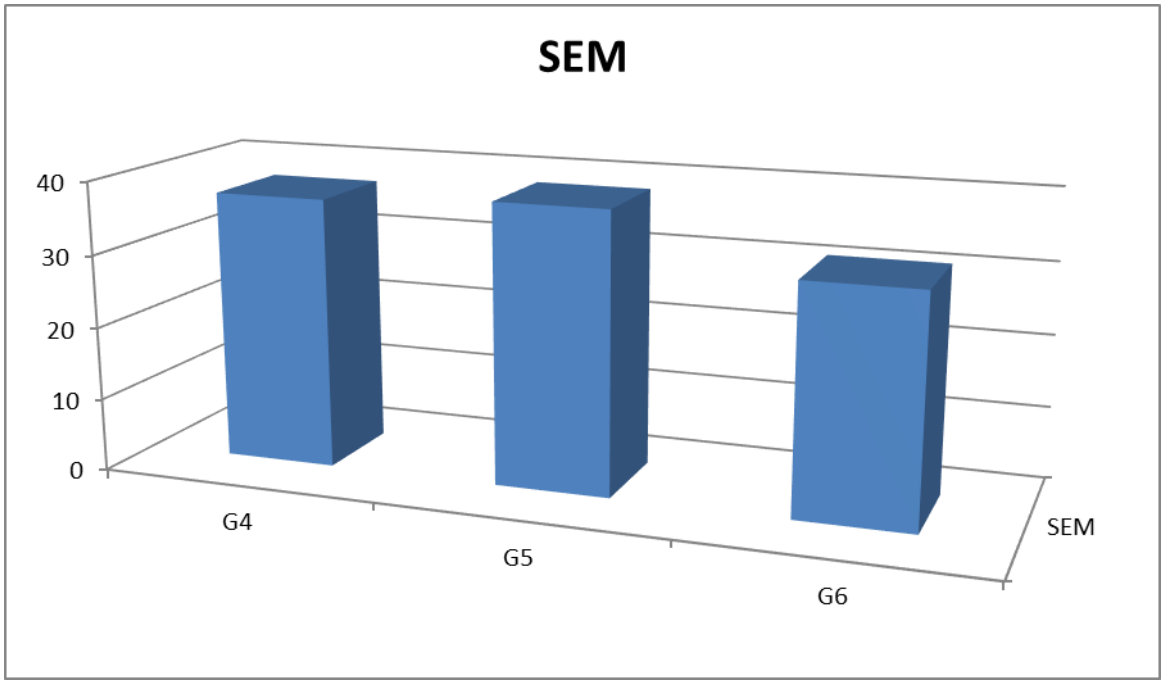

Figure 2: Difference between groups for SEM.

Discussion

Different file systems with constant taper have given clinicians the ability to machine predictable shapes (using constant taper files) that ultimately leads to synchronicity between the preparation and the master conefit (using laser verified cones to ensure accuracy). The most important factor in establishing endodontic synchronicity is that it reduces dramatically the need to widen the canal preparation in order to accommodate specific heated obturation techniques. Embracing this concept of endodontic synchronicity, and taking it to a more

sophisticated level in obturation, are sealer -based obturation systems such as the Activ GP Obturation System and EndoSequence BC Sealer (Brasseler USA). These are sealers that do not shrink.[9]

However, from a historical perspective, it is important to realize that Activ GP was the first one-cone technique to gain widespread acceptance. Activ GP has been and still is a system which utilizes improved glass ionomer technology (both as a sealer and as a special glass ionomer coated gutta-percha cone) to create a true one-cone obturation (10). Activ GP obturation requires a minimal amount of sealer, rather than the excess that is utilized in other methods. This is because the system is precision based (synchronized). The net result is an obturation technique similar in results to other more popular methods but easier to use. In a study published in the Journal of Endodontics in 2008, Fransen, et al[11] at Baylor University compared the sealing ability of single cone Activ GP with glass ionomer sealer to the warm vertical compaction of gutta-percha with AH Plus Sealer (DENTSPLY) and to the warm vertical compaction of Resilon (SybronEndo) with Epiphany sealer (SybronEndo). Their conclusion was: "In summary, there was no statistically significant difference for any of the parameters tested between the 3 obturation systems tested. Based on these results, the single cone Activ GP/GI sealer system has potential as an obturation system to provide a seal comparable to that achieved with other popular obturation system".

As previously mentioned, synchronicity in endodontics can be established as a result of the accuracy created between the preparation and the master cone. Similar to the regular gutta-percha, all Activ GP points are laser verified (and calibrated) to precisely match the preparations made by the 0.04 or 0.06 constant tapered EndoSequence file system. The precision matching of the primary cone to the preparation (endodontic synchronicity) is very important with any obturation technique because the accuracy of the conefit to the preparation minimizes the amount of tooth structure removed and reduces the amount of sealer. Furthermore, due to the predictability of shape associated with constant tapers, it may be stated that any true one-cone technique should be accomplished with a constant tapered preparation such as a 0.04 or 0.06. A variable taper technique is not recommended because its lack of shaping predictability (and its corresponding lack of reproducibility) will lead to a less than ideal conefit. This lack of endodontic synchronicity is why all variable taper preparations are associated with thermoplastic techniques.[12]

While glass ionomer deserves credit in establishing a true one-cone filling technique, there have always been those clinicians who question the handling characteristics of the material. Also, there have been those dentists who do not care to mix any cements. They would prefer a premixed delivery system, which they believe will ensure a consistent mix. While these folks may not like the specific material itself (glass ionomer), they do understand the concept and merits of one-cone obturation technique. The good news here is that the entire concept of a one-cone obturation technique has taken a giant step forward, and this giant step is the introduction of bioceramic technology to the world of endodontic obturation.

The science associated with bioceramic technology has generated a number of biocompatible ceramic materials specifically designed for use in medicine and dentistry. Systematic research of ceramics for use in

biomedical applications began in the early 1970s, and over the past 40 years, the application of a variety of ceramics in biomedicine has greatly expanded.[4] "Bioceramics" include alumina and zirconia, bioactive glass, glass ceramics, calcium silicates, coatings and composites, hydroxyapatite and resorbable calcium phosphates, and radiotherapy glasses.[3,13,14]

Bioceramics are widely used for orthopedic applications such as joint or tissue replacements and for coating metal implants to improve their biocompatibility. Additionally, porous ceramics such as calcium phosphate based materials have been used for filling bone defects.

The present study showed that use of files with constant taper property had large effect on obturation with use of bioceramicselear that lesser leakage penetration longitudinally was seen with lesser gap width recorded with such technique with highly significant differences.

Conclusion

The constant taper preparation fit more to bioceramic obturation loading and this evident with lesser interfacial gap formation and better leakage results.

Conflicts of interest

The authors reported no conflict of interests.

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