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Research Article

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The Use of Micro-Computed Tomography for Evaluation of Internal Adaptation of Dental Restorative Materials in Primary Molars: An In-Vitro Study

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ABSTRACT

Aim: To evaluate the internal adaptation of some dental adhesive restorative material (Nano-composite resin /Biodentine, Nanocomposite resin / Nano- resin-modified glass ionomer and Nano-composite resin) to the primary dentinal surface using micro-computed tomography (Micro-CT) Materials and methods: Forty-five extracted primary molars, due to caries or orthodontic reasons, were collected provided that it has an intact buccal/ lingual surface(s) and one half to two-thirds of root length. The selected teeth were disinfected and stored in normal saline at room temperature. The teeth were randomly assigned to one of the three experimental restorative groups according to the restoration type (15 per group): group A: Nanocomposite resin / Biodentine, group B: Nanocomposite resin / Nano-resin-modified glass ionomer and group C: restored totally with Nanocomposite resin. A high- resolution desktop micro-CT (Model 1172, Skyscan, Belgium) was used to image the samples. Results: The mean rank of volumetric dimension values of the total gap at the restorative material – dentine interface demonstrated significant difference among the three groups (P= 0.003). Moreover, there was a significant difference in the mean rank of the ratio of total gap volume/cavity volume among the three restorative groups (P=0.015). The data demonstrate that group A showed the lowest in total gap volume and mean ratio of total gap volume /cavity volume while group C recorded the highest value. Conclusion: Biodentine exhibited a higher internal adaptation to a dentinal surface which is comparable to Nano resin-modified glass ionomer. The study results potentiate the importance of using Biodentine liners under Nano-composite (sandwich technique) in terms of excellent internal adaptation, in addition to its high biocompatibility and easy handling as well.

Key words: *Micro-Computed Tomography (Micro-CT), Adhesive Dental Materials, Internal Adaptation, Extracted Primary Molars.*

INTRODUCTION

Until now the most prevalent childhood disease in the world is dental caries. Dental caries occurs due to the action of acids on the enamel surface [1]. The treatment for a carious lesion to save the affected tooth is eradication of the demineralized tooth structure, then placement of a dental filling. One of the main objectives of tooth restoration is protection of exposed dentin against bacteria and their toxins. In order to obtain an optimal clinical performance, prevent recurrent caries and preserve pulp vitality, the adequate bonding of the dental restorative material to cavity margins and internal dentine surfaces should be achieved. [2-4]

Microleakage is defined as passage of bacteria, fluids or ions between the wall of the prepared cavity and the dental restorative material. Microleakage can occur either on the outer tooth surface or at internal tooth restoration interphase. Inadequate internal adaptation and resulting interfacial gaps at tooth-restoration interfaces may cause post-operative hypersensitivity to cold, pain on mastication and pulpitis could occur due to poor internal adaptation often generated by dimensional changes of adhesive restorative material due to polymerization shrinkage and the difference in the physical properties between the tooth structure and restorative materials. [5, 6]

Multiple dental restorations are currently used to restore esthetic and/or function. Resin composite has good esthetic and capability of forming a bond to enamel and dentin, thus its application in the restorative field has been increased. However, polymerization shrinkage of resin composite will result in a gap formation, leakage and marginal discoloration. Nano-filled composite is a new brand of composite resin, which has been produced with nanofiller technology and formulated with nanomersand nanocluster filler particles. [7] It has a unique internal structure and properties, and containnanofillers that are 0.005 to 0.01 micron in size. The nanocomposite showed excellent polish ability, excellent translucency and retention comparable to those of microfillcomposite, at the same time it maintains physical properties and wear resistance. [8, 9]

KetacNano (3M ESPE) is a new generation of resin-modified glass ionomer (RMGI) which combines resin-modified glass ionomer cement advantages together with nanofiller technology. It is based on a simplified dispensing and mixing system (paste/paste), which provides faster, easier, less messy and more reproducible dispensing and mixing. Filler used is a fluoroaluminosilicate glass of size less than a micron (average 1 micron) and nano-fillers (5-25 nm) and nanocluster fillers (1.0-1) derived from silica and zirconia. The use of a priming step, without separate conditioning step, ensures better adhesion of the cement to the tooth surface. It has better polish ability than other RMGI restorative cement and fluoride ion dynamics comparable to another glass ionomer. Nano-ionomer is a good candidate for restoring primary and permanent teeth due to its improved properties. Physical properties of nano-ionomer exceed those of other popular RMGI restoratives. [10, 11]

Biodentine is a new bioactive dental material in the field of dentistry. It is one of the recent bioactive calcium-silicate based materials. Biodentine consists of a tri- and di-calcium silicate powder with calcium carbonate, iron oxide and zirconium oxide as the radiopacifier, mixed while the liquid component consists of an aqueous calcium chloride solution as an accelerator and a modified polycarboxylate as super plasticizing or water "reducing agent". [12-15] Biodentineas a dentine substitute that has many good properties such as fast setting time and high biocompatibility. Moreover, its compressive strength is high, sealing ability is excellent, and handling is ease as well. [11-13, 16, 17] It has adentine-like mechanical properties. The elasticity modulus of the cement and micro-hardness in addition to compressive and flexural strengths are comparable with natural dentin. [18, 19] So it can be used as a dentine replacement in the tooth crown and root region. It can be also used in maintaining the vitality of the dental pulp or stimulation of hard tissue regeneration.

Evaluation of microleakage or internal adaptation of dental restorations have been attempted using different methods. This approach involves soaking a restored tooth in a dye solution which is "an organic dye or silver nitrate solution" vertically sectioning through the restorations; the dye penetration depth in these sections are measured and reported as microleakage by scanning electron microscopy, or autoradiography. [20, 21] A semi-quantitative score related to the degree of dye leakage is determined according to the non-parametric scale for microleakage evaluation, which makes the test itself not very reliable. Moreover, this evaluation is done in the plane through which the sample is sectioned, means the presence or absence of the dye in the particular section. Microleakage can also be detected by submerging the restored tooth in water, then exposing the tooth to air pressure; but this method is not accurate because microleakage can be present in the restorative materials itself resulting in false increase of tooth restoration interphase microleakage. Therefore, development of techniques with precise information is necessary to accurately quantify interfacial gap or leakage. [10, 22, 23]

Due to the advanced researches in the field of imaging/tomography techniques, the internal three-dimensional microstructures (3D) can be reconstructed and monitored non-destructively. Micro-computed tomography (micro-CT) is an example of this advanced technology. Micro-CT allows imaging of the interior microstructure of the subject using a micro-focus X-ray source and collects the projected images by a planar X-ray detector. A series of X-ray images along continuous planes are captured from a rotating object to obtain 3D of the interior microstructures of small objects with high spatial resolution. These measurements have nondestructive nature, which permits further evaluation on the intact samples. It is considered as an important tool in many academic laboratories and industrial researches. [24-26] In biomedical field research, micro-CT has been used for examining a wide range of specimens including mineralized tissue such as bones and teeth, materials such as ceramics and polymers. In the field of tissue engineering, it is useful to show the structural features in scaffolds and the resulted tissue regeneration. [27, 28] Regarding dental materials, micro-CT has been used to investigate the structures at tooth-restoration interfaces for evaluation of polymerization shrinkage, internal adaptation and microleakage of the dental restoration. It gives the 3D reconstruction of the whole dental restoration and the surrounding dental tissues. [28, 29]

As the presence of the gap at the tooth-restoration interface may result in treatment failure, therefore, the aim of this in vitro study was to compare the internal adaptation of nanocomposite resin/biodentine, Nanocomposite resin/Nano-resin-modified glass ionomer and Nanocomposite resin full restoration to the primary dentinal surface by non-destructive assessment using micro-computed tomography (micro-CT). The null hypothesis was that there would be no difference in internal adaptation among the three tested groups.

MATERIALS AND METHODS

Selection and preparation of teeth

Forty-five extracted primary molars, due to caries or orthodontic reasons, were collected from pediatric dentistry clinics at the faculty of dentistry and University Dental Hospital, King Abdulaziz University (KAU), Jeddah, Kingdom of Saudi Arabia. The teeth should have intact buccal or lingual surface(s) and one half to two-thirds of root length to be included in the study. The selected teeth were disinfected and stored individually in normal saline in labelled containers at room temperature.

Cavity preparation

Standardized class V cavities were prepared on the buccal or the lingual surface of the teeth. The cavity was prepared with # 330 carbide bur on a high-speed hand piece with water coolant and care was taken that cavity margins were surrounded by enamel. The cavity dimensions measured approximately “5mm mesiodistal width, 3 mm occlusal-gingival height and 1.5 mm axial depth”. The outline dimension was cut on a matrix band for standardization. The Cavo-surface walls finished to a butt joint.

Cavity restoration

The teeth were randomly divided into three restorative groups (15 teeth each):

Group A: Nano-composite with Biodentine(Nanocomposite /Biodentine sandwich technique).

Group B: Nano-composite with Nano resin-modified glass ionomer (Nanocomposite /Nano RMGI sandwich technique).

Group C: Nano-composite full restoration.

Restorative materials were applied to the prepared teeth following the manufacturer instructions. All the restorations were cured by the same light-curing unit (POLYlux II, KaVoDentalGmbh, KG, Germany). One dentist has carried out all the procedures. The teeth were thermocycled for 500 cycles “between 5° and 55°C with a dwell time of 30 seconds” to subject the restorations to temperature extremes comparable to that of the oral cavity. Then all teeth were stored in normal saline until subjected to X-ray micro-CT investigation.

Table 1: Restorative Materials:

Materials	Product	Manufacturer
Nano- composite	Filtek™ Z250 XT Universal Restorative.	3M ESPE, Dental Products, USA
Biodentine	Septodont	SeptodontSaint-Maur-des-Fossés, France
Nano- resin-modified glass ionomer	Ketac™ N100 (Nano-RMGI)	3M ESPE Seefeld, Germany

Assessment of Internal adaptation (Sample micro-CT acquisition)

The samples have been imaged using desktop micro-CT “A high-resolution, Model 1172, Skyscan, Belgium” by an investigator blinded to the type of restorative materials. The micro-focus x-ray source was set at “100 kV of acceleration voltage, 100 µA of beam current”. Scanning was done at 13.4 µm resolutions and 0.5 mm Al and CU filter and the rotation step, rotation angle: was 0.60° with about 1490 seconds camera exposure time positioned middle-far. After scanning and reconstruction was done for all groups of teeth, analysis of the images was carried out using CTAn software (SKyscan) and 3D models of the teeth were created using CTvol software (SKyscan). [26]

Statistical analysis

Statistical analysis was carried out using SPSS “version 20”. Comparison of the values determined by micro-CT in three groups was carried out using a Kruskal-Wallis test. P value < 0.05 was considered significant.

RESULTS

Statistical analysis of the mean rank of volumetric dimension values of the cavity outlines in the three restorative groups demonstrated that there was no significant difference (P=0.783), this assures that cavity preparation procedure maintained standardized dimensions.

Applying Kruskal-Wallis Test to study the difference in the outcome of applying the three restorative groups showed that the mean rank of volumetric dimension values of the total gap at the restorative material – dentine interface demonstrated significant difference among the three groups (P= 0.003). Moreover, there was a significant difference in the mean rank of the ratio of total gap volume/cavity volume among the three restorative groups (P=0.015), table (2), figures (1), (2).

Table 2: Comparative analysis of the Cavity Volume, Total Gap Volume and Ratio of Total Gap Volume to Cavity Volume among the Tested Restorative Groups.

Dependent Variable	Group	N	Kruskal-Wallis Test	
			Mean Rank	P value
Cavity Volume	A	15	22.20	0.783
	B	15	21.23	
	C	15	24.57	
	Total	45		
Total gap volume	A	15	17.87	0.003*
	B	15	18.83	
	C	15	32.30	
	Total	45		
The ratio of total gap volume to cavity volume	A	15	18.73	0.015*
	B	15	19.27	
	C	15	31.00	
	Total	45		

*Significant P. at <0.05 level

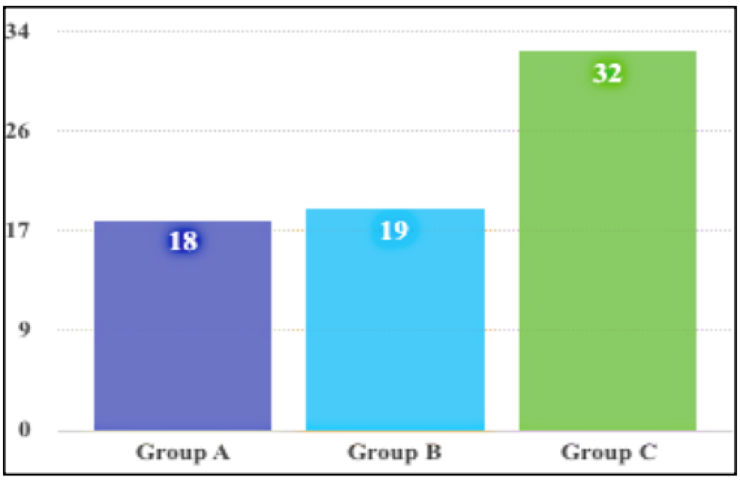

Figure 1: Comparisons of mean rank total gap volume between the three restorative groups.

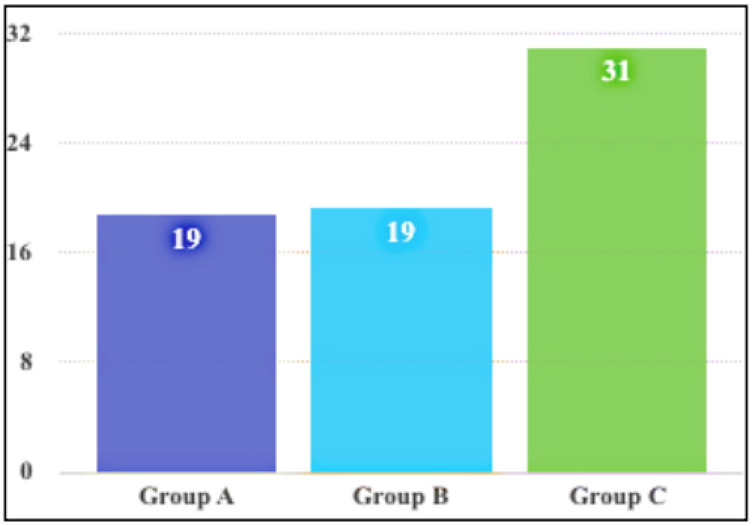

Figure 2: Comparison between the mean ratio of total gap volume/cavity volume of the three restorative groups.

Tables 3 and 4 showed the significant difference between group A and group C and between group B and group C, while there is no significant difference between groups A and B regarding total gap volume and mean ratio of total gap volume/cavity volume. The data demonstrate that group A showed the lowest total gap volume and mean ratio of total gap volume /cavity volume while group C recorded the highest value.

Table 3: Post-hoc Comparisons of Total Gap Volume between the Tested Restorative Groups.

Total gap volume	N	Post - hoc Test	
		Mean Rank	P value
Group A	15	17.87	1.000
Group B	15	18.83	
Group A	15	18.83	0.015*
Group C	15	32.30	
Group B	15	17.87	0.008*
Group C	15	32.30	

*Significant P. at <0.05 level

Table 4: Post-hoc Comparisons of Mean Ratio of Total Gap Volume/ cavity volume between the Tested Restorative Groups.

Total gap volume	N	Post - hoc Test	
		Mean Rank	P value
Group A	15	19.27	1.000
Group B	15	18.73	
Group A	15	19.27	0.042*
Group C	15	31.00	
Group B	15	18.73	0.031*
Group C	15	31.00	

*Significant P. at <0.05 levels

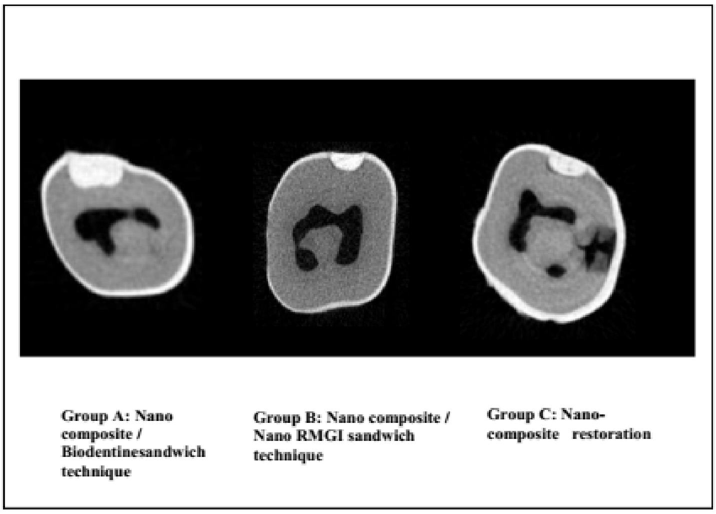

Figure 3: Micro-CT 3D reconstruction images of the three restorative groups teeth showing: very little internal gap in group A, an internal gap in group B, a more internal gap in group C. Gaps are represented with colored areas in the cavity preparations.

DISCUSSION

Restorative dentistry has been developed and changed over the past decade. The concept of "Extension for Prevention" by Sir G. V. Black is replaced by "restriction with conviction" with the advent of adhesive dentistry. The clinical success of adhesive dental restoration depends on its ability to minimize the extension of microleakage between the restoration and the tooth surface. Polymerization shrinkage, interfacial gap formation and leakage are still a challenge of composites restoration. An advancement in the technology and restorative techniques were attempted to develop a higher adhesion that can overcome composite shrinkage due to polymerization, dentine-restoration interface improvement and achieve a long-life restoration.

Evaluating the efficacy of the dental restorative materials to seal the internal tooth structure is assessed most commonly by measuring the internal gab. Microcomputed tomography is relatively new to dental research, but its potential is tremendous. The proposal for micro-CT evaluation provides a reproducible and nondestructive method to show and measure the gap produced at the interface of tooth surface and restoration. Recent studies have evaluated the internal adaptation of dental adhesive restorations using Micro- CT techniques. [20, 26, 30, 31]

The current study aimed to assess and compare the internal adaptation of three restorative groups (Nano-composite resin /Biodentine sandwich technique, Nano-composite resin /Nano-RMGI sandwich technique and Nano-composite resinfull restoration) by quantifying the internal gaps at tooth – restoration interface in 3 dimensions using the recent advent of microcomputed tomography (Micro-CT). A high-resolution desktop micro-CT "Model 1172, Skyscan" was used to image the samples.

The current study revealed that there was a significant difference in the value of internal adaptation between the three groups. Nano-composite with Biodentine group exhibited the lowest internal gap value followed by Nano-composite with Nano resin-modified glass ionomergroup, while the group of Nano-composite full restoration showed the highest internal gap value.

These results could be justified by that the application of sandwich technique comprising the advantage of both Nano-composite with Biodentine in group A and Nano-composite with Nano resin-modified glass ionomer in group B to counteract the composite resin restoration polymerization shrinkage; which is stronger than composite -dentine interface; the adhesion interface failure and the generated gap.

In group A, the nanostructure of calcium silicate materials in Biodentine has the ability to create hydroxyapatite crystals through the entire interface between the dentinal surface and the restorative material on hydration which helps to close the gap between the dentine-tooth interface and the dentine-composite interface. This provides better application of the material onto the surface and good internal adaption and seal ability. This in accordance with other researchers who revealed that dentine micromechanically bonds to the tooth without any pretreatment of the tooth surface. It is highly alkaline hens causes caustic erosion of the dentin and penetrates into the dentinal tubules and seals to the dentin. [32-36]

Regarding group B, the Nanofilled glass-ionomer type contains fluoroaluminosilicate glass, together with nanomers and nanoclusters in the filler loading. The higher filler loading in the nanofilled type may result in reduction in polymerization shrinkage and in coefficient of thermal expansion, enhancing the long-term bonding to tooth structure. Moreover, the low modulus of elasticity or a stress breaker of the Nano resin-modified glass ionomer layer would then provide enough flexibility to compensate for the tension generated by polymerization shrinkage. In addition to its excellent wetting and adaptability to the tooth surface, hence enhancing the chemical bonding and ensuring This is in an agreement with previous studies stated that the “sandwich of glass ionomer, dental adhesive and composite resin was proposed as an effective technique for both anterior and posterior resin-based restorations creating the optimal combination of desirable properties in a restoration”. The growing evidence that glass ionomers have a key role in maximizing the success of composite resins. [8, 37-40]

CONCLUSION

The use of micro-CT tool for evaluation of the quality of restorative dental materials showed that Biodentine exhibited a higher internal adaptation to the dentinal surface which is comparable to Nano resin-modified glass ionomer. The study results potentiate the importance of using Biodentine liners under Nano-composite “sandwich technique” in terms of excellent internal adaptation, in addition to its high biocompatibility, high compressive strength and easy handling as well.

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