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PIEZOELECTRIC REPEATED SCALING EFFECT ON MARGINAL LEAKAGE OF TWO DIFFERENT CEMENTED CERAMIC CROWNS

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ABSTRACT

Purpose: The purpose of the present study was to assess the influence of repeated piezoelectric ultrasonic strokes on the marginal leakage of different ceramic cemented crowns.

Materials and Methods: Forty human maxillary first premolars received full coverage standardized preparation 1mm above the cemento-enamel junction (CEJ). All teeth were classified into 2 groups (n=20) related to the type of the examined ceramic material; high translucent zirconia (HTZ) and hybrid resin ceramic (HRC). After all the fabricated crowns cementation with self-adhesive resin cement, each group was later partitioned into 4 subgroups (n=5). This was based on the amount of exposed ultrasonic scaler strokes. Microleakage assessment of buccolingual sectioned samples was performed, after their immersion in 2% methylene blue (MB) dye. Stereomicroscope was used for dye penetration measurement.

Results: The highest leakage percentage was recorded for HTZ, while the lowest mean value was achieved with HRC. The difference between the two groups was statistically significant (P= 0.022 <.05) as reported by one-way ANOVA. 7 years of scaler strokes for HTZ showed the highest microleakage mean with statistical significant difference p=0.008 between the subgroups. All the subgroups for HRC showed statistical insignificant difference with p=0.728**.**

Conclusions: Piezoelectric ultrasonic scaling has minimal effect on microleakage behavior of the ceramic crowns within clinical accepted range. The material type significantly affected the marginal leakage.

KEY WORDS: Marginal leakage, Piezoelectric scaling, High translucent zirconia, Hybrid resin ceramic.

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INTRODUCTION

Oral hygiene maintainace is crucial for overall body health. Periodic elimination of supra and subgingival microbial biofilm is critical for preventing plaque and tartar production, in addition to the control of inflammatory gingival and periodontal disorders. The quality of the patient's oral and prosthetic restorations hygiene has a significant impact on the longevity of any permanent restoration.

Prior to sonic and ultrasonic scalers were developed for plaque management and gross scaling, microbial biofilm was managed with hand tools such as hand scalers. Power-driven ultrasonic scalers transform electric energy into ultrasonic waves via piezoelectricity or magnetostriction. Piezoelectric units are reactivated with vibration that produces tip movement. They oscillate primarily linear in direction, which is parallel to the tooth surface and gently remove biofilm attached to tooth with correct alignment of the tip[(1)].

Ceramics have been used for esthetic dentistry with a new classification system, which classified all-ceramic materials into; glass-matrix ceramics, polycrystalline ceramics and hybrid ceramics. Zirconia was classified as polycrystalline ceramics with effective rehabilitation choices for indirect anterior and posterior tooth restorations. Because of their superior mechanical qualities and endurance, they are widely used in dentistry. By modifying its microstructure and composition, highly translucent zirconia ceramics have been recently developed. Hybrid dental ceramics are formed of polymer matrices, which aim to combine ceramics and resins. They showed adequate physical and optical properties with acceptable marginal integrity of the restoration [(2)].

Resin cements are used for luting of all these types of esthetic restorations, as they have high durability and bond strengths to the tooth structure and ceramics. In addition to their high tensile and compressive strengths and lowest solubility comparable to other available cements [(3)].

Marginal leakage has implication in variety of conditions that ended to failure of restorations. Microleakage analysis, which employs organic stains such as methylene blue, is one of the most commonly used methods for assessing the sealing performance of restorative materials. The simplicity, the reproducibility and the ability to detect marginal discrepancies are from the technical advantages of this method [(4)].

Microleakage tests can provide useful information about the prostheses materials efficacy. So this study was conducted with the consequences of piezoelectric ultrasonic scalers periodic use and its influence on the marginal leakage of zirconia and hybrid ceramic crowns cemented with resin cement. The null hypothesis for this research was; piezoelectric ultrasonic scaling will not influence the marginal leakage around cemented ceramic crowns.

MATERIALS AND METHOD

Sample size estimation

Sample size was calculated by G-power (software3.1.9.7 for Windows, Heinrich-Heire, Dusseldrof, Germany) using F test – ANOVA: fixed effects, omnibus and one way. For the two tested groups regarding pervious study [(5)], each subgroup contained at least 4 samples. Extra sample was added to each subgroup for results confirmation. . An alpha level α was set to 5% with a significance level of 95%, and a beta error β was accepted up to 20% with a power of study of 80%.

Preparing samples

According to ethical protocol (no. 482/2021) for Faculty of Dentistry, Minia University, a total of 40 human maxillary premolars were freshly extracted for orthodontic purpose, which had been collected

from the out patients' clinic of surgery department, Faculty of dentistry, Minia University. The teeth were selected with approximately the same coronal dimensions for this in vitro study. The premolars were examined to be free of caries, cracks and restorations. Each tooth was subjected to scaling and root planning with an ultrasonic device (Guilin Woodpecker Medical Instrument Co., Guangxi, China) for residual organic tissue removal. The teeth were disinfected and stored in 0.1% thymol solution.

Dental surveyor (Marathon-103 surveyor, Microtech co., Saeyang, Korea) was used for centralizing the premolars vertically up to 3mm above CEJ in clear epoxy resin blocks (Kemapoxy, Chemicals for Modern Building International, Giza, Egypt) in a multi-hole Teflon mold. Ensuring standard preparation evaluation, addition silicone index was made (Hydrorise, Zhermack, Italy) and sectioned buccolingual. Also pre-operative scanning was done by intra oral scanner (MEDIT I500, Seoul, Korea) for standardization confirmation. Reduction with low speed handpiece (NSK, Japan) was attached to the dental surveyor. Premolars were prepared with a standard method to receive full veneer crowns (Figure 1), with total convergence angle 12 degrees. The occlusal reductions for functioning cusp and non-functioning cusp were 1.5mm, 1mm respectively. The axial reduction and heavy chamfer finish-line were 1.5mm, 1mm respectively. The finish line position was 1mm above cementoenamel junction.

Crowns Fabrication

Both zirconia and hybrid resin crowns were designed to be fully anatomic with Exocad DentalCAD (Plovdiv 2.4, Exocad GmbH, Germany). The tested materials composition and their producers are described in Table (1). All ceramic crowns were designed using the same set of criteria, with 0μm space from the start point at the edge of finish line margin up to 1mm axially. The preoperative scans were duplicated to ensure that each produced premolar had the same morphological characteristics. The cement gap was 50μm. 5-Axis dental milling machine (DWX-52D, Roland DGA

TABLE (1): Tested materials composition and their producers

Material name	Composition	Description	Producer
High translucent zirconia Zyttria Z402	Zirconium oxide and Hafnium oxide >94.2% Yttrium oxide >5.7%, Silicon oxide < 0.01% Aluminum oxide 0,09 : 0,15%	Yttrium stabilized zirconia extra-translucent plus white Disc	*CO.N.CE.P.T. (Compagnia nuove ceramiche per la tecnica), Musini, Busseto (Pr), Italy*
Hybrid resin ceramic Vita Enamic	Silicon dioxide 58 – 63% Aluminum oxide 20 – 23%, Calcium oxide < 1% Sodium oxide 9 – 11%, Potassium oxide 4 – 6% Boron trioxide 0,5 – 2%, Zirconia < 1%	Structure-sintered ceramic matrix, the pores of which are filled with a polymer material Blocks	*VITA Zahnfabrik H. Rauter GmbH & Co.KG, Bad Säckingen, Germany*
Self-Adhesive Resin Cement Theracem	Calcium Base Filler 20 – 50% Glass Filler 30 – 50%, Dimethacrylates20 – 50% 10- methacryloyloxydecyl dihydrogen phosphate (MDP) Ytterbium Fluoride 5 – 15%, Amorphous Silica 1 – 5%, Initiator1 –10%	Dual - cure auto-mixed cartilages with continuous calcium/ fluoride ion release	*BISCO, Schaumburg, U.S.A.*

Corporation, Japan) was used for ceramic crowns milling. Zirconia crowns were sintered for 12 hours at temperatures ranging from 900◦ to 1200◦.

Crowns cementation

Zirconia crowns fitting surfaces were sandblasted for 10sec with 50μ alumina particles at the distance of 10mm with 3bars pressure. While HRC crowns were etched by 4% buffered hydrofluoric acid gel (BISCO, USA) for 60sec and rinsed thoroughly with water. Then all the manufactured crowns were cleaned in a deionized water bath using an ultrasonic cleaner for debris and alumina particles removal. After cleaning the prepared teeth with brush and pumice for 10sec, dentin conditioner (3M Deutschland GmbH, Germany) was applied to the bonding surfaces using cotton pellet. Following complete rinsing with water, drying with cotton pellets was done.

Self-adhesive dual-cure resin cement was applied against the internal walls of crowns, which were slowly seated to its antagonist prepared teeth. 5Kgs static load was applied to each crown using special custom made load applicator apparatus. Initial light curing was done for 2-3sec for all crown aspects, followed by removal of the excess cement around the crown margins. The final light curing was performed for 30sec (Figure 2) with wave length of 420-480ɲm and light intensity of 1000-1200m W/cm2 and distance of no more than 10mm. Self-curing was held under the load for 5min. According to ISO/TC 11405:2003, the cemented premolars were stored in separate 30ml distilled water storage containers for 24hrs.

Piezoelectric ultrasonic scaler strokes application

Considering frequent oral hygiene recalls twice a year, each group of cemented ceramic crowns was subdivided into four subgroups based on the amount of scaler strokes used; A1 and B1 (n=5 each) were stored subgroups, A2 and B2 (n=5) each were subjected to 6 full repeated strokes representing 3 years, subgroups A3 and B3 (n=5) for each received 10 complete repeated strokes representing 5 years and A4 and B4 (n=5) each underwent 14 full repeated strokes indicating 7 years.

A custom-made manufactured device was employed to accomplish standard scaling, by fixing scaler handpiece in position. Piezoelectric ultrasonic scaler gingival treatment tips were used, with half of the strokes using the G2 tip and the other half using the G4 tip.

Tips 0◦ angulation to the crown margins, the instrumentation was applied parallel to the tooth-crown margin interface. The tip lateral side was utilized to trace the crown-enamel interface for 15sec on each aspect of the cemented ceramic crown

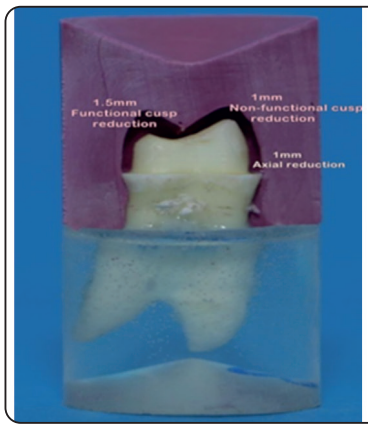

Fig. (1): Reduced premolar with index

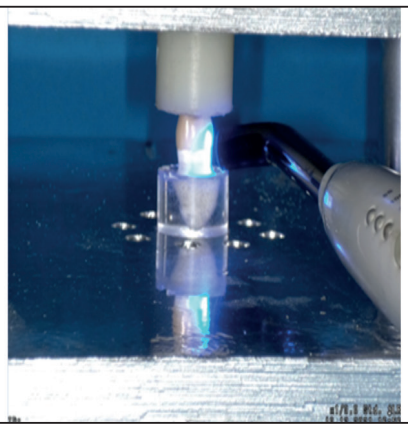

Fig. (2): Light curing under static load

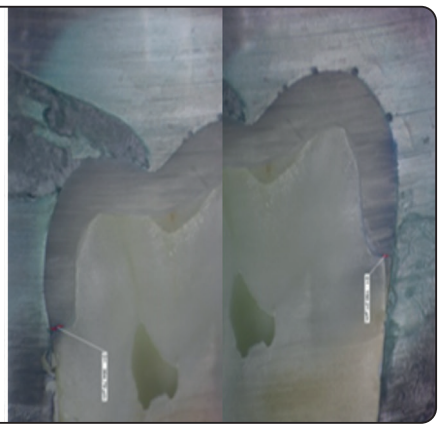

Fig.(3): Stereomicroscope images

margin with medium power "4" under enough water coolant. Each whole stroke cycle lasted 60sec that represented every 6 months periodic hygiene care.

Marginal leakage testing

At CEJ, samples were painted with a second coating of nail varnish. At room temperature, each sample was put in a separate 30ml container with 2% aqueous MB solution for 24hrs. Washing of all samples was done under running water, then left to dry.

Each sample was capped with epoxy fabricated for easy buccolingual sectioning with diamond disc attached to electric precision cutting saw (Isomet 4000 Linear Precision Saw, Lake Bluff, Illinois, USA). Using a stereomicroscope (Nikon MA 100, Japan) at 50X magnification, half of the sectioned specimens were imaged and analyzed at the buccal and lingual edges. Image analysis software (Omnimet, Buehler, USA) was used to analyze all recorded specimens images for linear dye penetration in μm (Figure 3). Leakage percentage was calculated according to ***Chang B. et.al, 2017***[6]:

$$\frac{\text{Linear distance of dye penetration}}{\text{Linear distance from the external crown margin to full axial distance}} \%$$

Scanning electron microscope (SEM):

For an explanation based on science, a specimen from each zirconia subgroup was randomly selected for SEM examination. Each specimen's surface was treated with fine coat ion sputtering. Under a scanning electron microscope (JSM-IT200 Jeol, Tokyo, Japan), the four specimens were analyzed. The photos were amplified to a magnification of X120 and examined.

RESULTS

Data from the two groups' outcomes was gathered, collated, and statistically examined. Means and standard deviations were used to summarize the data. One-way analysis of variance (ANOVA) test was used to compare more than two independent normally distributed subgroups. An alpha level of 5% was used with significance level of 95%, and a beta error up to 20% was tolerated with an 80% power of test.

Repeated strokes effect on marginal leakage percentage for different ceramics

Regarding zirconia independent samples t (student's) test statistical significant <.05 (Table 2), subgroup4 had the greatest mean for microleakage, whereas subgroup1 had the lowest one. The mean of subgroup 3 was statistically significant when compared to subgroups 1 and 2. Furthermore, subgroup 4 was statistically significant in comparison to the other zirconia subgroups. Using an independent samples t (student's) test, the tested groups were compared within each subgroup. On the other hand, HRC subgroups' means and standard deviations were statistically negligible.

Long-term time intervals impact on leakage

Comparison showed subgroup4 (7yrs) had the greatest mean microleakage with a statistically significant difference from untreated subgroup1 (0yr) (Table 3). The greatest microleakage mean was found for 7yrs repeated strokes with a statistically significant difference p=.021.

Dye penetration performance of various ceramics

Microleakage percentage means and standard deviations for groups A and B were 7.694±3.357 and 5.558±1.789 m, respectively Table (4). With $p=.022$, the results revealed a statistically significant difference between the two ceramic groups. The zirconia group had the highest leakage mean. The hybrid resin ceramic category had the lowest average.

Scanning electron microscope

The enlarged SEM images of the various zirconia subgroups revealed that subgroup 3 had cement degradation, which worsened with subgroup 4.

TABLE (2): Comparison between the tested groups within each subgroup using independent samples t (student's) test:

Microleakage (%)	Zirconia Group A	Hybrid Resin Group B	P value between groups A and B
0 year (Subgroup1) Mean ± SD	5.472±0.522[a]	4.966±1.707[a]	p=.591[NS]
3 years (Subgroup2) Mean ± SD	6.618±2.531[ab]	5.218±2.180[a]	p=.434[NS]
5 years (Subgroup3) Mean ± SD	7.113±1.133[b]	5.644±2.462[a]	p=.037*
7 years (Subgroup4) Mean ± SD	11.573±3.182	6.405±0.829[a]	p=.020*

: Statistically significant NS: Not statistically significant Statistically significant if <.05

Same letters within the same column means are not significantly different.

TABLE (3): Comparison between different time intervals

Marginal leakage (%)	**Time interval**			
	0 year	**3 years**	**5 years**	**7 years**
Min. – Max.	**3.307-7.269**	**3.371-9.429**	**3.026-8.840**	**5.514-15.918**
Test of Significance *p* value		***p*=.021***		

Statistically significant if <.05 *: Statistically significant

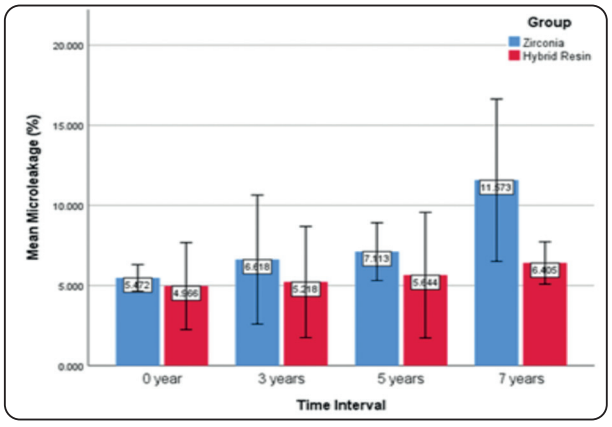

Fig. (4): Bar chart of Mean of Marginal leakage (%) by Subgroups by Time Interval

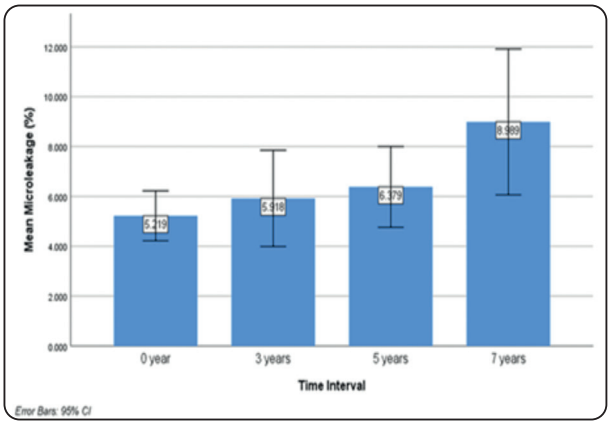

Fig. (5): Clustered Bar graph of Mean of Marginal leakage (%) in different time interval

This might lead to an increase in the microleakage percentages for the examined subgroup Figures (7-10).

TABLE (4): Comparison between performances of both groups

Marginal leakage (%)	Zirconia group A	Hybrid Resin group B
Min. – Max.	**3.607-15.918**	**3.026-8.840**
Test of Significance p value	**p=0.022***	

Statistically significant if <.05 *: Statistically significant

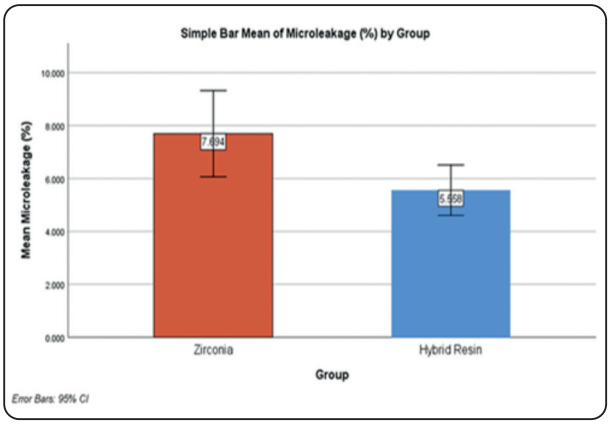

Fig. (6): Bar graph of Mean of Marginal leakage

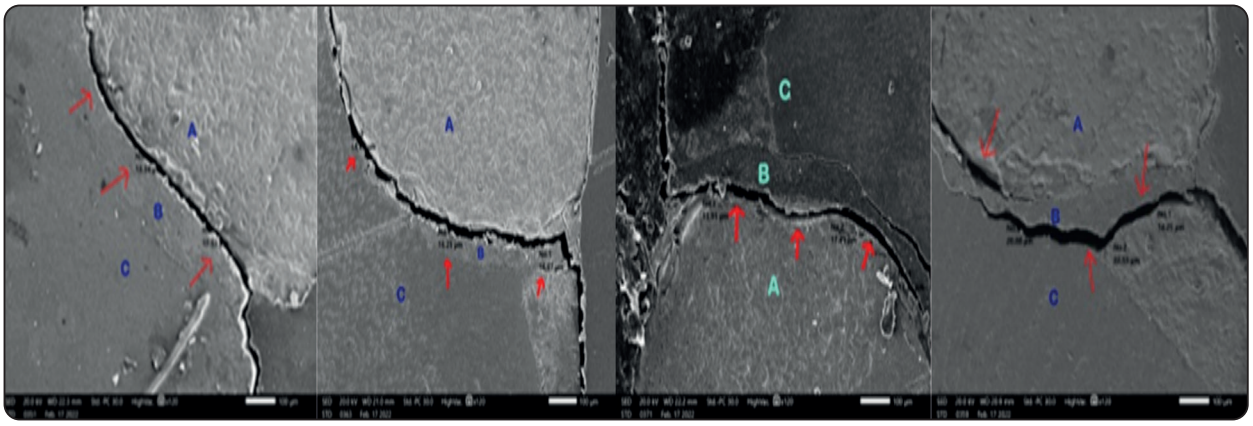

Fig.(7): Specimen-subgroup1 Fig.(8): Specimen-subgroup2 Fig.(9): Specimen-subgroup3 Fig.(10): Specimen-subgroup 4

A, B and C represent zirconia, resin cement and dentin respectively. Arrows showed the cement gap between zirconia crown margin and cement interface

DISCUSSION

This investigation was carried on to evaluate the effect of repeated piezoelectric ultrasonic strokes on marginal leakage of high translucent zirconia and hybrid resin ceramic. According to the results of the present study piezoelectric scaler had significant effect on zirconia microleakage, so the alternative hypothesis was accepted, although the hybrid resin ceramics showed neglectable effect.

Oral hygiene procedures are linked to plaque control sessions, effective prosthetic therapy and increase the restoration's durability. In addition to basic home care, supportive periodontal treatment is recommended twice a year. Oral hygiene is essential for socializing, functioning, and keeping a high quality of life [7]. Dental biofilm is formed when periodontal care is neglected, which ends up to restorations failure [8].

This laboratory research, like the others, aimed to quantify the prosthetic materials' performance in a controlled environment that mimicked clinical situations. For any In-vitro research including variables, standardization procedures are the most accurate ways. This will guarantee that the results have high power and that sample fabrication bias is minimized.[5] In the present study, human natural

teeth were selected due to their natural elastic characteristics, bonding capability and strength that better matching the clinic situations [10].

This research samples were manually generated using a handpiece coupled to a dental surveyor. This provided for tooth wear and cutting depth control, which is critical for emulating indirect restoration tooth preparations [11,12]. In the current investigation, minimally invasive preparation for all-ceramics was followed since it assists in the long-term durability of restorations.[13] As a result, minimum material thickness parameters related to manufacturers' instructions were established, which was similar for both material types utilized to fabricate the current research crowns. The preparation convergence angle has a direct impact on crown resistance and retention. According to ***Ebadian B.et.al, 2021***[14], total convergence 12° was employed in the current investigation to get lesser microleakage values [14]. Furthermore, it has the capability to reduce frictional resistance during crown seating.

The restorative ceramic material used in this study meet all of the criteria for appropriate restorative material aesthetic needs, mechanical requirements, the color of the dental substrate, and parafunction behaviors[9]. ***Church TD.et.al, 2017***[15] ***and Sen N.et.al, 2020***[16] both declare that high-translucency monolithic zirconia has outstanding aesthetics, great strength qualities, and good biocompatibility. As it possesses ideal flexibility, stress resistance, and light conductivity, hybrid ceramics enable combining the advantageous qualities of ceramics and composites, providing greater visual adaptability [17,18]. Furthermore, they are less abrasive on the opposing dentition.

Restoration retention and sealability are affected by the cementation protocol. Furthermore, the cement inclusion of a functional monomer, such as 10-MPD, might strengthen bond strength via being mechanically stronger due to its higher penetration and lower viscosity [19]. Before using self-adhesive cement, the dentin was pretreated with dentin conditioning to optimize bond strength values [20, 21].

Professional oral hygiene care is normally conducted biannually for moderate-risk patients at 6months fixed intervals will manage and enhance patient oral health outcomes [22, 23]. The number of cycles was established based on the average service life of fixed prosthesis. The instrumentation parameters in this investigation were 0 degree tip angulation with a medium power setting, which was based on minimum root roughness.

According to ***Mahiroglu MB.et.al, 2020***[24], ***Vengatachalapathi H.et.al, 2017***[25] and ***Sinha A.et. al, 2019***[26] smoother resulting surface is required for minimum bacterial adherence. Under the same forces, piezoelectric scalers left smoother root surfaces than magnetostrictive scalers [24]. The important terms should be regarded during ultrasonic scaling; lateral force, power setting, working tip form, and angulation according to research ***Babina K.et.al, 2021***[18].

Although methylene blue particles are smaller than the usual size of bacteria, dye immersion techniques were simple to use to assess leakage [27]. For all dyes, the depth of penetration may be assessed under the stereomicroscope [28]. This evaluation process is primarily a qualitative and quantitative assessment approach for displaying dye penetration patterns.

This research demonstrated a statistical significant increase in dye penetration for zirconia after 5 and 7 years of repetitive strokes, hence the relative hypothesis was accepted. Previous studies for long-term assessment did not conduct with the same time periods. Non-treated and three-year samples were unaffected confirming the findings of ***Azer 2020***[5], ***CHANG B.et.al, 2017***[6] and ***Lei JI. et. al, 2020***[29]. While ***Eggmann F.et.al., 2021***[30] had shown that marginal degradation of ceramic crowns occurs with frequent use of ultrasonic instruments. This theory is consistent with the findings of the current investigation, which revealed a considerable increase in microleakage after 7yrs of repetitive strokes.

The null hypothesis was rejected, although the microleakage raise was statistically negligible to the maximum repeated strokes for the hybrid resin ceramic utilized in the current investigation. This was explained by ***Bajraktarova-Valjakova E.et.al, 2018***[31] who stated that HRC act as shock absorbent restorative material. These hybrid group values agreed with ***Badawy HM.et.al, 2018***[32], who investigated microleakage of hybrid ceramic crowns using two CAD/CAM scanning techniques. When the findings of both groups were compared, the zirconia group had a much greater microleakage percentage with mean±SD 7.694±3.057 than hybrid resin group with mean±SD 5.558±1.789.

Several prior investigations, examined microleakage when ultrasonic scaling was used but only for short time periods. There were no other researches in the literature comparing the effect of long-term exposure to piezoelectric ultrasonic scaling on marginal leakage of teeth reconstructed with zirconia and hybrid resin.

All oral cavity factors, such as occlusal pressures, the presence of varied volumes of saliva with changing pH and bacteria were not simulated, that was considered the limitation of test methods applied in this research. It does not precisely replicate real-life oral circumstances, and further clinical research is required before application in general clinical practice.

CONCLUSIONS

Within the limitations of the present study, the following conclusions can be withdrawn:

1. Piezoelectric ultrasonic long-term scaling has clinically acceptable leakage behavior for zirconia crowns.
2. Marginal leakage was significantly affected by the ceramic material type which was lesser for hybrid resin ceramics.

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