Research article

Comparison of survival time of three adhesive materials used in fixed space maintainer cementation by using ball milling machine: An in vitro study

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Abstract: Background: Premature primary tooth extraction causes loss of arch length, therefore; space preservation is a critical step to prevent space closure that can lead to future malocclusion. This can be achieved by using a space maintainer. Thus study's objective was to assess and contrast the survival of three different luting materials used to cement fixed space maintainers an in vitro study. Materials and Methods: This study used 30 extracted human third molars without caries, cracks, or chemical pretreatment. They were divided into three groups of ten samples (n = 10). The adhesives selected in this study were Relyx Luting 2 (resin modified glass ionomer), TOTALCEM (self-etching, self-adhesive, resin cement, dual cure) and Transbond Plus Light Cure band adhesive (compomer). Manufacturer recommendations for bonding were followed after cleaning and polishing for all surfaces of the teeth. To distinguish the specimens, the middle of the root was drilled with a handpiece and marked with a red marker, then incubated for 24 h at 37 °C before being transferred to a ball mill machine to induce mechanical stress. The machine was opened to check for any failed specimen. This continued until all bands were removed from the teeth. The data was analyzed using log-rank Kaplan-Meier and Bonferroni post hoc tests at p 0.05. Results: the mean survival time of bands cemented with TOTALCEM and RelyX Luting 2 significantly longer than bands cemented with Transbond Plus Light Cure band adhesive (P<0.001). Conclusion: band retention with TOTALCEM and RelyX Luting2 superior than bands cemented with Transbond Plus Light Cure Band Adhesive.

Keywords: adhesives, ball mill, luting cements, space maintainer, survival time.

Introduction

Children's primary teeth are valuable. They are essential for mastication, phonetics, aesthetics, and maintaining the space for permanent teeth. Dental arch integrity and permanent tooth space are two of the many functions of the primary dentition. Children with unhealthy diets have an increased risk of developing tooth decay, which may end with extensive crown restorations and early tooth loss [(1)]. Early loss of primary dentition causes drifting and space loss [(2)], which can cause well-known issues like tooth malposition, overcrowding, ectopic eruption, impacted tooth, and deprived molar relationship [(3)].Fixed appliances called "fixed space maintainers"(SM) are used to keep the space available so that the unerupted tooth can be guided into the right position in the arch [(4)].

The most frequent SM utilized when a primary molar is extracted too soon is the band and loop space maintainer [(5)]. This type can be manufactured easily, with low cost and well tolerated by children. Although the advantages of band and loop space maintainer, it does have certain drawbacks. Failures in the cement and breaks in the solder connection in the band and loop space maintainer are two of its most significant downsides [(6)].

The cement lute plays an important role in the band's retention. Several investigations had been carried out to look into the improvements in the realm of luting cements [7]. Glass ionomer cements (GIC) have gained a lot of popularity since they bind to metal and enamel, ion releasing ability (Fluoride), and have an antibacterial effect. The biggest drawback of glass ionomer is that they might become contaminated with moisture while they are setting, and the maximal binding strength is only attained after 24 hours [8].

Resin-modified glass ionomer (RMGIC) is considered advancement in glass ionomer technology. It advantages over GICs include low solubility, the capacity to chelate enamel and metal through an acid–base reaction, tolerance to moisture, and high tensile and compressive strength, respectively [9]. Compomer (polyacid modified composite resin) is a combination of GIC and composite resin, which mixes the properties of these two materials [10]. Through photo polymerization, which employs energy to activate photo-initiators and produce radical polymerization equal to that of a resin composite, in this situation the setting process is started [11]. In 2002, a type of resin-based material was introduced called self-adhesive resin materials. They were designed to replace many traditional cement driveways. They combined the positive properties of different materials, like adhesives and conventional luting. The two mechanisms that aid in the development of adhesion are micromechanical retention and chemical retention between acidic monomer groups and hydroxyapatite[12].Self-adhesive cement do not require tooth surface pretreatment ,therefore; it will reduce the number of bonding steps, decrease clinical working time[35].

The fatigue life of a "material is "defined as the number of repetitive loading cycles it can endure before complete failure". Stress-life plot, which summarizes the damage nucleation, damage accumulation, and failure processes of a material into a single, empirical connection, is frequently used to illustrate this behavior [13]. The fatigue is one of the major reasons for fracture of materials [14].

Ball mill fatigue testing cements yields reproducible results in a short time that match clinical performance. The fatigue test cannot quantify loads developed, but it does simplify clinical conditions. The slow cracking of pre-chipped cement and mechanical destabilization from the spheres are the most likely causes of failure [27]. The objective of the study was to make a comparison and assessment of the survival time of bands cemented with different cement type after a ball milling simulation of mechanical fatigue stress

Materials and methods

Ethical approval was submitted to the Ethical Committee in Baghdad University College of Dentistry NO: 555322 in 17 April 2022. A sample of 30 human third molars previously extracted and stored in 0.1% concentration of thymol particles (V/W) and distilled water after extraction and subjected to periodic change to avoid dehydration and microbial growth [15]. The samples were collected from patients complained from soft tissue impaction their age was (19 – 27) years old. Duration of sample collection was four months. A 20X stereomicroscope (Kruss, Germany) was used to examine teeth. Teeth with Caries, cracks, restorations, and chemical pretreatment were excluded [16]. Thirty orthodontic stainless steel bands were used in the study (IOS, USA). The teeth were cleaned with non- fluoridated pumice (i-Faste, Siauliai, Lithuania) for 10 seconds with aid of polishing brush and slow speed handpiece then washed and dried [17]. The teeth were divided into 3 groups each group had 10 teeth. The bands were cemented on the teeth immediately after the cleaning and polishing procedure had been done by following the manufacture instructions:

Relyx Luting 2 (3M, USA), a resin modified glass ionomer, was used to bond 10 specimens. It was applied to the interior surface of the band after being mixed with cement using a spatula, and it was then light-cured for 20 seconds from the occlusal surface using a led type light cure device (woodpecker, China).

10 specimens, TOTALCEM (ITENA, FRANCE) (self-etch /self-adhesive resin cement/ dual cure) was immediately applied to the interior surface of the band using an auto mix tip that was included in the

material's kit, and then light-cured for 20 seconds. Transbond plus Light Cure band adhesive (3MUnitek, USA) (compomer) was used to bond 10 specimens. It was applied directly to the interior band surface using a tip that was included in the kit of the material, and it was then light cured for 20 seconds from the occlusal surface.

After bonding procedures had been done the middle of root surface used for identification between the specimens, by making marks with the aid of hand piece. All of marks then colored with the aid of red colored pen marker to ease the differentiation between the specimens. The red marker left to dry. After completion of samples preparation, the specimens then collected together in one container contained distelled water and incubated in 370C for 24hours[18][19] prior to the test to mimic the intraoral environment [20]. After the incubation period had been completed; the specimens were transferred to the lab to be tested. The test was achieved at the University of Technology in materials engineering department, powder technology lab. A machine that would induce mechanical fatigue is called a ball mill machine. The type of machine used was a roller ball mill (Capco, UK). This machine contains two rollers, a ceramic container, a protective shield, a motor and also supplied with spheres to mill the materials used in this machine as illustrated in Figure 1.

Figure 1: Roller ball mill during operation

The total weight of the selected spheres was 470 ± 1 g [21] measured by using sensitive scale (kern ,Germany) .The machine was operated at 100 rounds per minute for one hour[21] , then the mill was opened to check for any debanded or loose specimens. Every specimen with a loose or removed band was excluded. Then the mill was closed and the process continued in this manner until all of the bands were removed. The ball mill was run for 10 hours in total.

Statistical analysis

Data Description, analysis and presentation were performed using Statistical Package for social Science (SPSS version -22, Chicago, Illionis, USA).Shapiro walk test was used to test the Normality sample distribution, Log Rank test was used to test the significancy among groups. Multiple Comparisons of survival time between groups by using Bonferroni post hoc test

Results

Normality test of survival time among groups showed that all the samples were normally distributed at $p>0.05$ for checking normality shapiro walk test Table 1. The descriptive statistics of fatigue survival time for every adhesive luting are given in Table 2 .Log Rank test was used to test showed the existence of significant differences among the groups ($P <0.05$) as showed in Table 2.

Multiple Comparisons of survival time between groups using Bonferroni post hoc test showed that there was no significant difference between TOTALCEM and RelyX Luting2 while there was highly significant difference between Transbond Plus Light Cure band adhesive and RelyX Luting2 and also with

TOTALCEM as showed in Table 3. Transbond plus LC band adhesive specimens (blue colour line) started to fail in the first hour of the beginning of the test, while the other remaining specimens that belonged to the same material failed in the 3rd and 5th h hours of the test, respectively. Relyx Luting 2 specimens (grey dot line) showed failure after 3 hours of the beginning of the test and gradually failed until all the specimens failed in the 9th hour of the test. TOTALCEM specimens (pink line) started to fail at the 4th hour ,and the remaining specimens failed gradually until the last hour(10th hour) as showed in Figure 2

Table 1: Normality test of survival time among groups.

Groups	Statistic	df	P value
RelyX Luting 2	0.899	10	0.211
TOTALCEM	0.902	10	0.229
Transbond Plus	0.868	10	0.095

Non-significant p>0.05

Table 2: Descriptive statistics of survival time among group

Groups	Mean	±SD	±SE	Min.	Max.	Log Rank	P value
RelyX Luting 2	5.500	2.014	0.637	3.000	9.000		
TOTALCEM	7.200	2.098	0.663	4.000	10.000	6.215	0.013 Sig.
Transbond Plus	1.800	1.398	0.442	1.000	5.000		

Sig= significant Min. = minimum, Max. = maximum,

Table 3: Multiple pairwise comparison of survival time among groups using

RelyX Luting 2	TOTALCEM	0.074	NS
TOTALCEM	Transbond Plus	<0.001	H Sig
Transbond Plus	RelyX Luting 2	<0.001	H Sig

Sig. =significant, NS= non-significant, H Sig = highly significant

The statistical analysis employed the following levels of significance: NS p>0.05, S 0.05 p<0.01 H

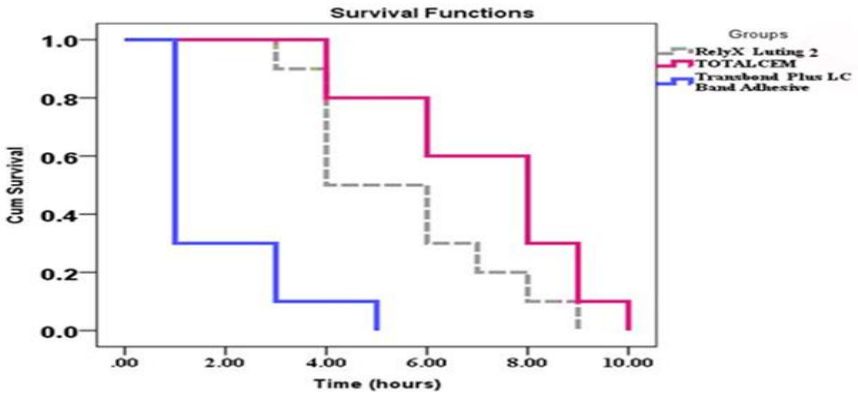

Figure 2: survival time of different adhesive materials

Discussion

The laboratory investigation evaluated the survival time of three different adhesive materials used for band cementation. As the results showed that the mean survival time of TOTALCEM(self-etch /self-adhesive)was longer than that of both RelyX luting 2 (resin modified glass ionomer) and Transbond plus light cure band adhesive (compomer) but statistically not significant with RelyX Luting 2 which is was in agreement with a study done by Cantekin et al[22] this may be due to that TOTALCEM is self-etch self-adhesive materials , and it has dual retention: micromechanical retention and also chemical retention this retention occur between monomeric acidic groups and hydroxyapatite. It has phosphoric acid groups within its multifunctional monomers, which demineralize and infiltrate enamel at the same time. The most important reaction in the cement setting process is radical polymerization. This reaction can be launched by light exposure or by the linking of cement monomers, which results in the production of high molecular weight polymers [7].

The resin-based self-adhesive cement that was investigated for this study contains a significant amount of adhesive acidic monomer to improve bonding to the adherent surface. As a result, these cements provide exceptional adhesion and remarkable mechanical strength in addition to low water sorption and expansion that they have [23]. Self-adhesive resin cements combine the benefits of resin cements' superior strength with low solubility [24].

Relyx luting 2 (RMGI) showed shorter mean survival time than TOTALCEM which might be due to this cement a double phase material. It contains a significant acid–base reaction as part of their overall curing process, as well as a free-radical resin polymerization reaction that can be initiated by light and/or chemically. A second polymerization reaction performs the fundamental acid-base curing reaction [25].During the early stages of setting, the RMGIC acid-base and visible light polymerization reactions may inhibit one another, which may explain the low bonding strength of RMGIC compared to TOTALCEM self-adhesive resin cement[26].

Transbond plus light cure band adhesive (compomer) showed shortest mean survival time than the other two materials ($p < 0.001$) since it consists of acidic monomers that can polymerize and ion-leachable glass particles. In the context of compomers there is no acid-base reaction like there would be in a RMGIC. A free radical polymerization reaction caused them to harden [28]. Water-absorption is an aim in the design of compomers [29] and dipping in water can cause their mass to expand by 2% to 3.50. Since they have a carboxylic group, they must be neutralized. Water absorption is required for neutralization. It is a relatively slow process that depends on the degree of water diffusion. Although it is a necessary step to assist neutralization, it was found that it has a negative effect on their mechanical properties. Contrary to the traditional composite resins, which are known to absorb reasonable amount of water but this mechanism doesn't cause significant changes to the mechanical properties [30]. The lower GI acid neutralization rate observed in RMGIs compared to compomer may be due to glass particle silane coatings, water replacement with monomer, and/or lower levels of polyacid [31].

Compared to the other two cements utilized in this study, the TOTALCEM luting agent has a high followability that has fine particle size and low viscosity, improving the bonding to the tooth surface [32].The bond failure of specimens in the ball mill machine was most likely arise from a process of delayed crack propagation that was induced within the luting material by the force of impact and the mechanical action of the ceramic spheres. The ball mill method uses a variety of forces ranging in severity [33]. The exact mechanism of band failure inside the ball mill was currently unknown, but it was thought to occur by the force of impact and the mechanical action of the ceramic spheres on the specimens, possibly leading to slow crack formation within the cement. The ball mill technique had proved to be an effective indicator for the clinical performance of these materials [34].

Limitation

Since it was An in Vitro study many factors related to the oral environment will not be accounted like the effect of saliva; therefor, further in vivo studies regarding these luting materials need to be conducted to check for their clinical validity.

Conclusion

TOTALCEM showed longer survival time followed by RelyX Luting 2; the shortest survival time was Transbond Plus light cure band adhesive therefore TOTALCEM can be used as luting material for fixed space maintainer cementation.

Conflict of interest

The authors have no conflicts of interest to declare.

Author contributions

SMZ and RA; study conception and design. SMZ; data collection. SMZ and RA; Methodology. SMZ and RA; statistical analysis and interpretation of results. SMZ, RA and BB; Writing - review and editing. Supervision; RA and BB. All authors reviewed the results and approved the final version of the manuscript to be published.

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المقارنة في وقت صمود ثلاث انواع من المواد المختلفة المستخدمة في لصق حاجز المسافات الثابت دراسة مختبرية

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المستخلص

الخلفية: يؤدي القلع المبكر للأسنان اللبنية إلى فقدان طول فك الاسنان ؛ يعد الحفاظ على الفراغ خطوة حاسمة لمنع إغلاق الفراغ الناتج عن الفقد المبكر للأسنان الأولية والذي يمكن أن يؤدي إلى سوء إطباق في المستقبل ويمكن تحقيق ذلك باستخدام حافظ الفراغ. كان الهدف من هذه الدراسة هو تقييم ومقارنة صمود ثلاثة مواد لاصقة مختلفة مستخدمة لصق حافظ المسافات بعد تعرضها الى اجهاد ميكانيكي باستخدام جهاز الطحن :دراسة مختبرية المواد والطريقة: تم استخدام لهذه الدراسة 30 سن عقل بدون تسوس أو تشققات أو معالجة كيميائية. تم تقسيم هذه الأسنان إلى ثلاث مجموعات من عشر عينات.(n = 10) تم تنظيف وصقل الاسنان لكي تكون جاهزة للصق المواد عليه . تم احضارثلاثين حلقة معدنية. تم لصق هذه الحلقات المعدنية على الاسنان باستخدام المواد الثلاثة TOTALCEM, RelyX Luting 2, Transbond PLUS LIGHT CURE band adhesive وفقا لتوصيات الشركات المصنعة للمواد. لتمييز العينات ، تم حفر منتصف الجذر بجهاز حفر الاسنان وتم وضع علامة عليها بعلامة حمراء ، ثم حفظت لمدة 24 ساعة عند 37 درجة مئوية قبل نقلها إلى مطحنة الكرة للحث على الضغط الميكانيكي. يتم فتح المطحنة كل ساعة بحثًا عن عينات منفصلة. استمر هذا حتى تم إزالة جميع الحلقات المعدنية الملصقة من الأسنان. تم تحليل البيانات باستخدام اختبارات Kaplan-Meierو Bonferroni اللاحقة ذات التصنيف اللوغاريتمي عند .0.05 p النتائج: كان متوسط وقت بقاء الحلقات المعدنية التي تم تثبيتها باستخدام TOTALCEM و RelyX Luting2أطول من تلك التي تم تثبيتها باستخدام . (P> 0.001) Transbond Plus Light Cure band adhesive الاستنتاج: أظهر TOTALCEM وقتًا أطول للبقاء متبوعًا بـ Relyx Luting 2 ، أقصر وقت للبقاء أظهره Transbond Plus Light Cure Band Adhesive