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Evaluation Of Bond Strength Of 3D Printed Space Maintainer And Conventional Band And Loop Space Maintainer: An In Vitro Study

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Abstract:
Background*: The most effective way of preventing future malocclusion from tooth loss is to place an effective, durable, and economical space maintainer. 3D printed space maintainers appear to be a promising alternative for preserving space when early loss of primary molars occurs. This study was conducted to test the bond strength of 3D printed bands and conventional metal bands.*
Materials and Methods*: In this in vitro study, the sample consisted of 14 second primary molars, where they were randomly allocated into 2 groups. Group A received custom made metal bands cemented with a glass ionomer cement (GIC). Group B received 3D printed bands cemented with resin cement. Each group was tested for shear bond strength.*
Results*: 3D printed space maintainer bands had a significantly higher value than conventional metal bands. (p<0.001).*
Conclusion: *3D printed bands showed higher bond strength than metal bands.*
Key Word*: 3D printing; Space maintainer; Bond strength; Band and loop*

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I. Introduction

The primary dentition plays a determining role in the child's growth and development of the occlusal relations and dentofacial structures.[1] The premature loss of primary teeth due to caries, trauma, ectopic eruption and many other causes can lead to undesirable tooth movements of primary and/or permanent teeth including loss of arch length[2].

The most effective way of preventing future malocclusion from tooth loss is to place an effective, durable, and economical space maintainer.[3] The conventional stainless steel band and loop (B&L) space maintainer is the most commonly used appliance among fixed space maintainers for single tooth loss. However, the fabrication of metal B&L consumes more time due to the laboratory work. In addition to many disadvantages as being embedded in gingival tissues, cement dissolution, esthetic insufficiency and being unable to prevent rotation and tipping of abutment teeth.[4,5]

Nowadays, digital technology has raised the bar for searching for an alternative to overcome the drawbacks of the metal B&L space maintainers. Since the introduction of three dimensional (3D) printing, its area of dental application has increased widely[6]. The advantage of using 3D scanning and printing in manufacturing space maintainers, is its ability to produce accurate custom made appliance without the need of impression making or laboratory work. In addition to, being cost and time efficient, as well as reducing the failure of the appliance as it is printed in one unit minimizing the chances of breakage.[7]

II. Material And Methods

The study was conducted at Dental Materials Laboratory, Faculty of Dentistry, Ain Shams University. The ease of debonding of both types of space maintainer bands cemented on extracted primary teeth were tested.
Study Design: Invitro study.
Study Location: Dental Materials Laboratory, Faculty of Dentistry, Ain Shams University, Cairo, Egypt.
Study Duration: August 2021 to January 2022.
Sample size: 14 second primary molars.
Sample size calculation: Sample size was calculated using G power program version 3.0.10 assuming a power of 80% and alpha=0.05.

Subjects & selection method: The second primary molar teeth were extracted due to orthodontic reasons. Cementation of the SM bands on the selected teeth specimens (n=14) with either of the following;
Group A (n=7) Stainless Steel bands cemented with glass ionomer cement
Group B (n=7) 3D printed band cemented with resin cement (n=7)

Inclusion criteria:

1. Intact enamel.
2. Absence of any crack because of extraction forceps or otherwise.
3. Non-carious.
4. No previous restoration.

Exclusion criteria:

1. Previously restored molars.
2. Presence of enamel defect.
3. Presence of any crack because of extraction forceps.
4. Carious tooth.

Procedure methodology

All the selected teeth were thoroughly cleaned from plaque and stored in distilled water at room temperature for no more than one month. The lower second primary molars were mounted with cold cure acrylic resin material (Cold Cure Base Material, Acrostone, Egypt) in polyvinyl chloride ring to the level of cement–enamel junction. The acrylic blocks were number coded, with a different number for each group of samples. For group A, an appropriate stainless steel band (3M, Unitek, Monrovia, Calif, USA) was selected and adapted to the best fit for each tooth. A 0.9 mm (0.036 inch) stainless steel wire was attached to the mid-buccal and mid-lingual side with hard solder to load the cell with the universal unit. The modified bands of the SM were cemented with glass ionomer cements (Ketac Cem radiopaque, 3M ESPE) according to manufacturer's instructions.(Figure1)

Group B, Teeth mounted in the acrylic resin were scanned using 3-shape E2 scanner.
Scanlt Manager Orthodontics software was utilized to scan the model. Special bands were designed with a hook to be able to be loaded to the universal testing machine. The bands were designed using 3Shape appliance designer module. (Figure 2) Phosphoric acid etchant (Universal Etchant Gel, 3M ESPE, USA) was spread over the enamel surface for 30 s and washed for 30 s. Excess water was eliminated using a spongy pellet, to get a moist enamel surface. A layer of the universal bonding agent (3M ESPE St Paul, MN, USA) was added to the etched enamel surface using a brush and cured for 20 s by using a light-curing device. Resin cement (G-CEM™ Capsule GC corporation, Tokyo, Japan) was spread to the surface of the tooth and cured for 40 s.
The bond strength was tested using a universal testing machine (Lloyd, LR-5K(Ametek – USA). using tensile mode, and the force was applied to the specimens was at 1 mm/min, a cross-head.123 (Figure3) Testing was done for each sample till the band was aloof from the tooth; the utmost force required to remove the band was recorded for every specimen and was measured in newtons.125 Then shear bond strength was calculated by dividing the peak load values by the band surface area (1 MPa = 1 N/mm2).

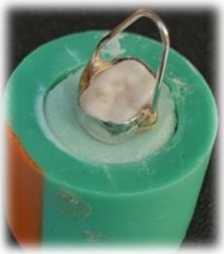


Figure 1: Group A

Figure 2 : Group B

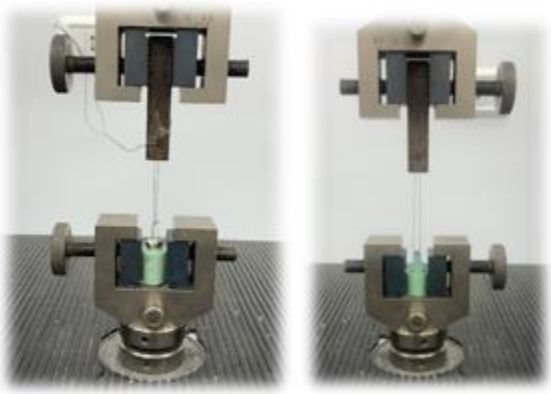


Figure 3: Force application to the specimens

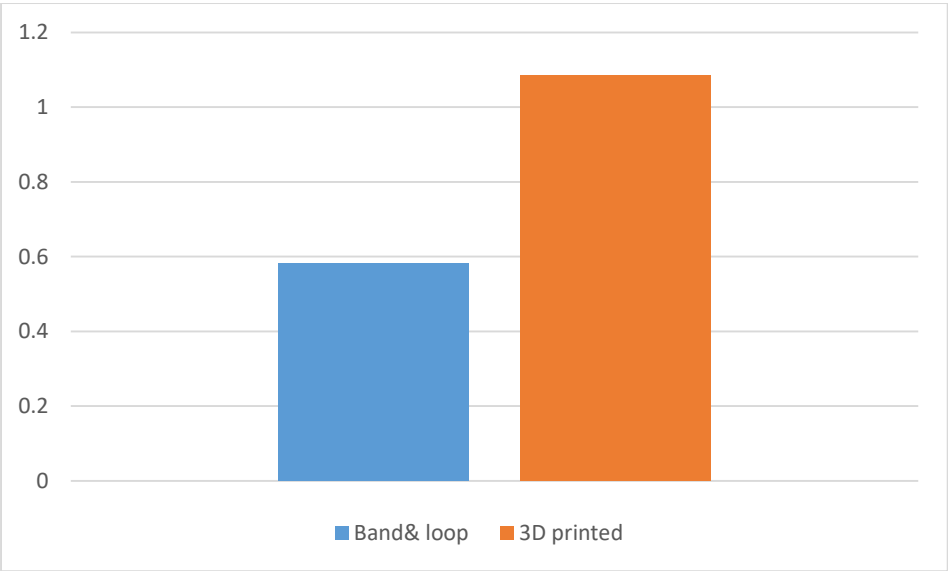
Statistical analysis

Statistical analysis was performed by R statistical analysis software version 4.1.2 for Windows. The data was presented as mean, standard deviation (SD) and percentage. They were explored for normality by checking the data distribution, and using Shapiro-Wilk test. The significance level was set at $P \leq 0.05$. Parametric data were analyzed using paired t-test.

III. Result

Paired t-test [Table (1) and Figure (4)] showed that 3D printed SM Group B had a significantly higher value than band and loop SM Group A ($p<0.001$).

Bond strength (MPa) (Mean±SD)		**p-value**
Band& loop	**3D printed**	
0.58±0.14	1.08±0.12	**<0.001***



IV. Discussion

Band & Loop is the most commonly used space maintainer in the event of premature loss of a single primary molar. This appliance however; has certain limitations which urged the need for newer materials and designs of appliances[8,]such as; prefabricated SMs, direct bonded (DB) SMs, and fiber-reinforced composite (FRC) SMs, which evolved parallel to improvements in resin composite materials and adhesive systems.

With the rapidly emerging technological advances, oral health industry has shifted its paradigm towards digital dentistry providing the best and minimally invasive, novel treatment options to the patients to choose from[9]. One of which is three-dimensional (3D) printing. GIC cement is most widely accepted for the cementation of SM band[10]because it can adhere to both enamel and metal. It also provides fluoride release and can facilitate fluoride uptake. Despite these advantages, the use of GICs has not eliminated the problem of cement failure, hence this study was conducted.

Regarding shear bond strength, the 3D printed band cemented with resin cement showed higher bond strength than conventional band cemented with glass ionomer cement. The results are in congruence to the earlier research done by Prabhakar et al.[11] who reported that the mean retentive strength was highest with resin cement followed by RMGIC, GIC, and bands without cementation, respectively.

In accordance to the results of the present study, Millett et al. [12] reported higher bond strength of dual cured resin cement when compared to conventional GIC (Ketac Cem). Self-adhesive resin has not been used for luting bands. However, studies are done previously to compare the shear bond strength of brackets bonded using self-adhesive cements.[13] It is noticeable that the greater retention shown by self-adhesive resin cement is due to micromechanical retention and chemical retention between monomeric acidic groups and hydroxyapatite.[14]

Kaur et al.[10], also reported that resin cement presented higher shear bond strength when compared to conventional GICs. On the contrary, previous studies done found that conventional GICs did not significantly differ from RMGICs. Catekin et al. concluded in their study that conventional GICs presented higher bond strength than resin-based cements for space maintainer cemented bands.

V. Conclusion

3D printed bands cemented with resin cement showed higher bond strength than conventional metal bands cemented with glass ionomer cement.

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