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Comparative Evaluation of Periodontal Health, Amount of Relapse and Incidence of Failure between Conventional and Customized 3D Printed Orthodontic Fixed Lingual Retainers: An In-Vivo Study

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Abstract

Aim: Comparative evaluation of periodontal health, amount of relapse and incidence of failure between conventional and customized 3D printed orthodontic fixed lingual retainers.

Material and Methods: A total of 34 participants were selected and randomly divided into two groups 'A' and 'B'. Participants of Group 'A' were bonded with Conventional Retainer and the participants of Group 'B' were bonded with the 3D Printed Retainer. Alginate impressions were made at T0 and T2 and Little's Irregularity Index was measured using digital Vernier Calipers. The participants were recalled at two different time intervals; T1 at three months & T2 after six months of bonding of the retainer and were subjected to various indices like Plaque Index, Gingival Index and Bleeding on Probing. Out of the 17 participants from each group, three were randomly selected and plaque samples were collected which were subjected to microbial culturing to estimate the microbial count and quantification of P. gingivalis microorganisms. The failure rate was recorded in terms of wire breakage and bond failure as and when reported.

Results: The plaque Index and Gingival Index scores were found to be higher in group 'A' when compared to Group 'B' (p value <0.001). Bleeding on probing was observed more in the participants of Group 'A' than Group 'B' (p value <0.001). The Little's Irregularity Index scores for both the groups showed that there was greater amount of relapse in the Group 'A' as compared to Group 'B' (p value = 0.001). Group 'A' exhibited higher failure rate than Group 'B'. CFU value was higher in Group 'A' samples than the Group 'B' samples, but not statistically significant. Neither of the samples showed the presence of P. gingivalis microorganisms.

Conclusion: 3D Printed Retainer was superior to Conventional Retainer in terms of Oral Hygiene, Amount of Relapse and Incidence of Failure.

Keywords: 3D printed lingual retainer, Conventional bonded lingual retainer, Efficacy of oral hygiene maintenance, Long term stability of retainers

I. INTRODUCTION

Orthodontic treatment has two phases, active phase and retentive phase. T. M. Graber defines retention as "holding of the teeth in optimal esthetic and functional positions". Retentive phase aims to preserve corrections that are achieved by the active phase. Retainers can be broadly classified as Removable and Fixed[1].

The teeth after orthodontic treatment tend to return to their initial positions. Relapse occurs due to the tension in periodontal fibers that are stretched during the tooth movement. Age related changes in the bone can also lead to relapse[2]. Hence achieving post-treatment stability is considered to be a prime concern for orthodontists[3].

Removable retainers[4] most commonly prescribed are Hawley's retainer, Begg's retainer and vacuum formed retainer[5]. The disadvantages of removable retainers are reduced patient compliance and poor stability in maintaining the alignment of teeth[6].

Fixed retainers[7] are bonded on to the lingual surfaces of the teeth using composite restorative material as shown in Figure 1. They are more effective in maintaining the corrected teeth positions as compared to removable retainers[6]. The most commonly used retainers are the maxillary Hawley's and the mandibular fixed lingual retainers[8]. Fixed retainers offer many advantages over the removable type, like reduced need for patient compliance, better aesthetics and predictable long-term stability. The multi-stranded wire retainer has become the gold standard for maintaining incisor alignment[9].

Figure 1: Conventional Bonded Lingual Retainer

The primary problem of multi stranded lingual wires is their high failure rate. Maxillary failures are reported to be greater than mandibular failures[10]. Studies indicate that 27.2%[11, 12] of bonded mandibular retainers and 58.2% of bonded maxillary retainers[13] fail during the retentive phase.. It has also been found that the plaque accumulation is more on the gingival aspect of the wire than on the incisal[11].

With the advent of 3D Technology, one of the recent advances in the orthodontic retention is the 3D printed fixed orthodontic retainer[14]. It is bonded on the lingual surfaces of anterior teeth. The fabrication of this type of orthodontic retainer is carried out initially by digital designing with the help of appropriate software. The retainer design will follow the lingual surfaces of maxillary or mandibular teeth away from occlusal interferences from the opposite arch dentition. This design will then be exported in stereolithographic format (.stl) and used for manufacturing of the retainer. One of the most recent methods of fabrication is direct printing or additive manufacturing of the .stl file in by Direct Metal Laser Sintering printers like EOS. In these machines metal powder is fused together according to 3D .stl file in layers using heat generated with a laser beam.

So to overcome the dilemma regarding assortment of appropriate retainer in day to day clinical practice, this study was conducted to compare two different types of fixed orthodontic lingual retainers i.e. Conventional Fixed Lingual Retainer (Multi-stranded Braided Stainless Steel) and Customized 3D Printed Fixed Lingual Retainer.

II. MATERIALS AND METHODS

The patients who completed their active phase of treatment and were ready for the retentive phase were selected as per inclusion and exclusion criteria of the study. The participants were divided randomly and equally into two groups, one of which was bonded with a Conventional Multi-stranded Braided Stainless Steel Fixed Orthodontic Lingual Retainer and the other group was bonded with a Customized 3D Printed Lingual Retainer.

After the completion of the active phase of orthodontic treatment, the arch wires were removed from patient's maxillary and mandibular arches and alginate impressions were made and poured in stone. Afterwards the arch wires were again placed back into the patient's mouth. For Group A, bonding of conventional retainer was preceded by thorough oral prophylaxis. Once the retainer was placed, fixed appliance was removed. For Group B, the study models were sent to laboratory for fabrication of 3D printed retainer. It was bonded on the anterior teeth following oral prophylaxis, followed by debonding of the fixed appliance (Figure 2).

Figure 2: 3D Printed Retainer

The bonding of both the retainers was carried out according to standard procedure[15]. Once the retainer was placed, estimation of the periodontal health was done at time intervals T1 (3 months after bonding of retainer) and T2 (6 months after bonding of retainer). The estimation of amount of relapse was done at time interval T2 (6 months after bonding of retainer) comparing it with readings at time T0 (at the time of bonding of retainer). And lastly the estimation of failure rates was assessed as and when the patients reported to the hospital.

❖ **Estimation of Periodontal Health:** For estimation of Periodontal Health, the following parameters were assessed:

- ***Clinical Parameters:-***
  1. **Plaque Index:** Plaque index as described by Löe H[16] was evaluated using William's periodontal probe and disclosing agent. Mean values were calculated and recorded for each individual tooth.
  2. **Gingival Index:** Gingival index as described by Löe H[16] was recorded on the lingual aspect by clinical examination.
  3. **Bleeding on Probing:** Bleeding on probing[17] was determined on clinical examination fifteen seconds after a William's probe was inserted into the gingival crevice.

- ***Microbial Parameters:-***

Microbial Load and *P. gingivalis* count estimation: Out of seventeen participants from each group, three participants were randomly selected and subjected to piloting for microbial load estimation as well as isolation and quantification of *P. gingivalis*. The plaque samples were collected using Gracey curette and transported in vials containing Tris-EDTA buffer to laboratory, where it was cultured in Blood Agar and the microbial load was determined in terms of Colony Forming Units. The obtained media was then subjected to Real-Time Polymerase Chain Reaction for isolation and quantification of *P. gingivalis* in the plaque sample.

❖ **Estimation of Amount of Relapse:** The amount of relapse was estimated by recording Little's Irregularity Index[18] (LII). The study models of the subjects were used to calculate the values for Little's Irregularity Index by measuring linear displacement between anatomic contact points in the anterior teeth using Vernier caliper.

❖ **Estimation of Incidence of Failure:** Incidence of failure was recorded for Wire Breakage and Bond failure between retainer and tooth surface at T1, T2, and as and when the patients reported.

III. RESULTS

Comparison of the Plaque Index (PI) at time T1 between the two groups showed that score was significantly higher in the Conventional group with a p value of <0.001. At time T2, PI was significantly higher in the Conventional group with a p value of <0.001. The PI difference was higher in the Conventional group and was statistically significant with a p value of 0.001 as shown in Table 1, Chart 1 and Chart 2.

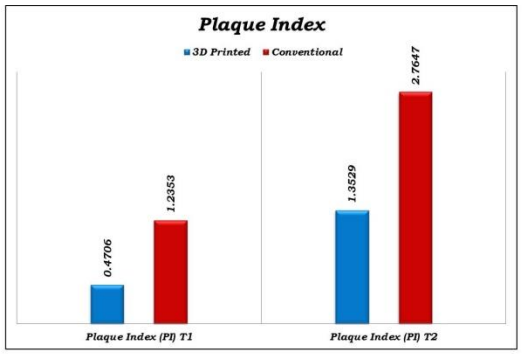

Chart 1: Comparison of Plaque Index among groups at T_1 & T_2

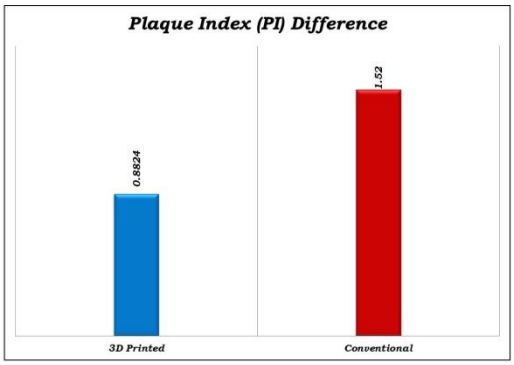

Chart 2: Differences in Plaque Index amongst the groups

Table 1: Independent t Test comparing the various parameters between the two retainers

	3D Printed (n=17)	Conventional (n=17)	t Value	p Value
	Mean ± SD	Mean ± SD		
Plaque Index (PI) T1	0.47 ± 0.51	1.24 ± 0.44	-4.67	<0.001
Plaque Index (PI) T2	1.35 ± 0.61	2.76 ± 0.44	-7.787	<0.001
Plaque Index (PI) Difference	0.88 ± 0.49	1.53 ± 0.51	-3.773	0.001
Gingival Index (GI) T1	0.06 ± 0.24	1.06 ± 0.56	-6.8	<0.001
Gingival Index (GI) T2	0.53 ± 0.62	1.94 ± 0.24	-8.691	<0.001
Gingival Index (GI) Difference	0.47 ± 0.62	0.88 ± 0.49	-2.148	0.04
Bleeding on Probing (BOP) T1	0 ± 0	0.35 ± 0.49	-2.954	0.009
Bleeding on Probing (BOP) T2	0.06 ± 0.24	1 ± 0	-16	<0.001
Bleeding on Probing (BOP) Difference	0.06 ± 0.24	0.65 ± 0.49	-4.417	<0.001
Amount of Relapse (LII Score) T0	0 ± 0	0 ± 0		
Amount of Relapse (LII Score) T2	0.02 ± 0.07	0.33 ± 0.31	-4.091	0.001
Amount of Relapse (LII Score) Difference	0.02 ± 0.07	0.33 ± 0.31	-4.091	0.001

Comparison of the Gingival Index (GI) at time T1 between the two groups showed that score was higher in the Conventional group and was Statistically Significant with a p value of <0.001. At time interval T2 it was significantly high in the Conventional group with a p value of <0.001. The GI difference between the two groups showed that score was significantly higher in Conventional group with a p value of 0.04 as shown in Table 1, Chart 3 and Chart 4.

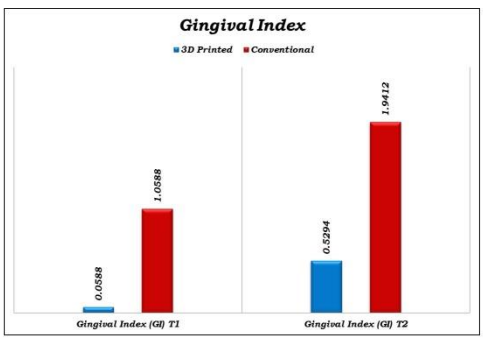

Chart 3: Comparison of Gingival Index among groups at T_1 & T_2

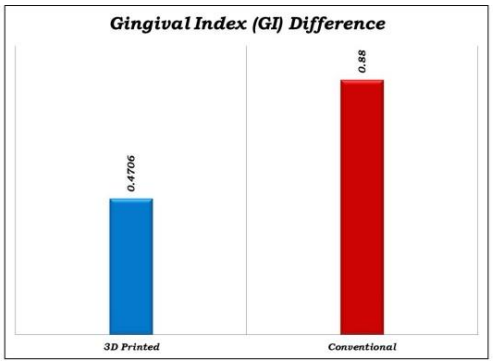

Chart 4: Differences in Gingival Index amongst the groups

Comparison of the Bleeding on Probing (BOP) at time T1 between the two groups showed significantly high score in the Conventional group with a p value of 0.009. At time T2 it was higher in the Conventional group and was Statistically Significant with a p value of <0.001. Comparison of the BOP difference between the two groups showed a high reading in Conventional group (p value <0.001) as shown in Table 1, Chart 5 and Chart 6.

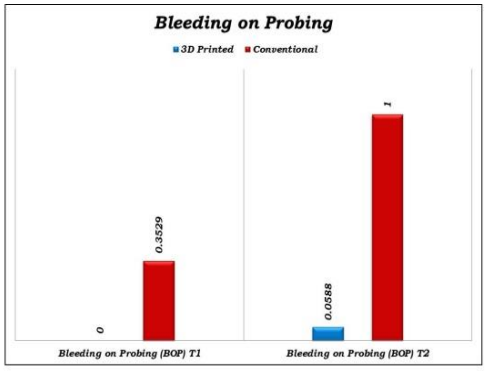

Chart 5: Comparison of Bleeding on Probing among groups at T_1 & T_2

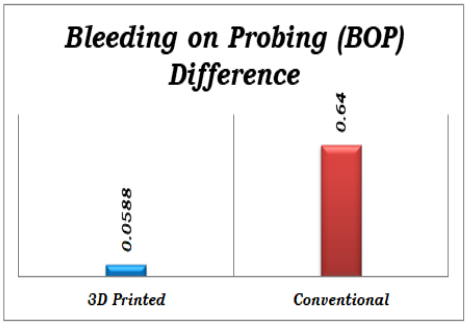

Chart 6: Differences in Bleeding on Probing amongst the groups

Comparison of the Amount of Relapse (LII Score) at time T2 between the two groups showed high scores in Conventional group and was Statistically Significant (p value 0.001). LII Score was significantly higher in Conventional group with a p value of 0.001 as shown in Table 1, Chart 7 and Chart 8.

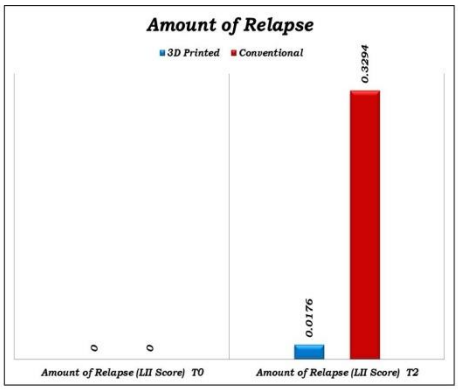

Chart 7: Comparison of Bleeding on Probing among groups at T_1 & T_2

Intragroup comparison of Plaque Index, Gingival Index, Bleeding on Probing and Amount of Relapse in the Conventional retainer group showed that all the values were higher at time T2 (Table 2). Similar comparison in the 3D printed retainer group showed that Plaque index and Gingival Index were significantly high at time T2, but bleeding on Probing and Relapse rate were not significantly high at time T2 (Table 3).

Table 2: Paired t Test comparing each parameter at both the different time intervals for Group 'A'

			N	Mean ± SD	Mean difference ± SD	t Value	p Value
Group 'A' (Conventional)	Pair1	Plaque Index (PI) T1	17	1.24 ± 0.44	-1.53 ± 0.51	-12.26	<0.001
		Plaque Index (PI) T2	17	2.76 ± 0.44			
	Pair 2	Gingival Index (GI) T1	17	1.06 ± 0.56	-0.88 ± 0.49	-7.50	<0.001
		Gingival Index (GI) T2	17	1.94 ± 0.24			
	Pair 3	Bleeding on Probing (BOP) T1	17	0.35 ± 0.49	-0.65 ± 0.49	-5.42	<0.001
		Bleeding on Probing (BOP) T2	17	1 ± 0			
	Pair 4	Amount of Relapse (LII Score) T0	17	0 ± 0	-0.33 ± 0.31	-4.44	<0.001
		Amount of Relapse (LII Score) T2	17	0.33 ± 0.31			

Table 3: Paired t Test comparing each parameter at both the different time intervals for Group 'B'

			N	Mean ± SD	Mean difference ± SD	t Value	p Value
Group 'B' (3D Printed)	Pair 1	Plaque Index (PI) T1	17	0.47 ± 0.51	-0.88 ± 0.49	-7.50	<0.001
		Plaque Index (PI) T2	17	1.35 ± 0.61			
	Pair 2	Gingival Index (GI) T1	17	0.06 ± 0.24	-0.47 ± 0.62	-3.11	0.007
		Gingival Index (GI) T2	17	0.53 ± 0.62			
	Pair 3	Bleeding on Probing (BOP) T1	17	0 ± 0	-0.06 ± 0.24	-1.00	0.332
		Bleeding on Probing (BOP) T2	17	0.06 ± 0.24			
	Pair 4	Amount of Relapse (LII Score) T0	17	0 ± 0	-0.02 ± 0.07	-1.00	0.332
		Amount of Relapse (LII Score) T2	17	0.02 ± 0.07			

IV. DISCUSSION

From this study, the comparison between the two types of retainers in terms of oral hygiene showed that the 3D printed retainer was superior to the conventional retainer. The results show significant differences between the two retainers in the plaque index, gingival index and bleeding on probing. The multi-stranded braided stainless steel lingual retainer accumulated greater amounts of plaque because of the increased surface area that is provided by the braids in the wire. The 3D printed retainer on the contrary had a smooth surface which accumulated less amounts of plaque, and as an added benefit it also facilitates efficient cleaning using the toothbrush.

A study conducted by **Levin et al**[19] showed that the multi-stranded bonded lingual retainer showed more plaque accumulation around the retainer. The periodontal health in case of bonded lingual retainers was comparatively poor but this difference was statistically insignificant, unlike in the present study. The study conducted by **Sam Foek et al**[20] showed that the mean survival rates of the mandibular bonded lingual retainer was 68.4% over a period of 41 months any incidence of failure of the retainers mostly occurred during the first six months of placement of the retainer. In the present study the greater rates of failure of the conventional retainer indicated similar results.

A study conducted by **Doldo et al**[21] on novel 3D printed bonded orthodontic lingual retainers showed that the customized retainer was superior to the conventional braided retainer in terms of periodontal health, patient acceptance and chair side time. In the study conducted by **Johnston et al**[2] it was said that the multi-stranded retainer wire bonded on the lingual surfaces tends to accumulate more amount of plaque and calculus as compared to the removable retainers. But this difference in the amount of plaque retention did not seem to have any deleterious effect on the periodontium in the long term.

Another study conducted by **Kanup et al**[22] that was aimed to compare a novel customized bonded lingual retainer with a conventionally used bonded lingual retainer in terms of periodontal health. They found that the customized lingual retainer was superior to the conventional retainer. Similar kinds of results were obtained in the present study.

Emilie Gelin et al[23] conducted a study comparing the conventional multi-stranded bonded lingual retainer with a customized 3D printed lingual retainer made of nitinol in terms of periodontal health and incisor position stability over 12 months period. Contrary to the results of the present study, the authors found no significant differences between the two types of retainers and both the retainers were found to be equally effective in maintaining good periodontal health and incisor position stability.

In this study it was clear that the amount of plaque deposits on the conventional retainer was more than that deposited on the 3D printed retainer. From the microbial culturing it was found that the microbial count in the plaque samples taken from the conventional retainer was more than that taken from the 3D printed retainer. The quantification of *P. gingivalis* was done to detect any chronic periodontal disease onset that was being caused due to the retainer. However in this study it was seen that the *P. gingivalis* was not found in quantifiable numbers from plaque samples collected from the conventional retainer or the 3D printed retainer.

In terms of stability, the Little's Irregularity Index was used to assess the incisors positions at the stipulated time intervals. The LII values for both the groups were zero at the time of bonding the retainers because they were placed after complete alignment of the teeth. When the indices were taken at time interval of six months from bonding of the retainers, it was found that some degree of irregularity was seen in patients bonded with the conventional retainers, when compared to 3D printed retainers.

The incidences of failure were counted in terms of wire breakage and bond failure of the retainers in this study. Out of the 34 patients

none of the patients reported to the hospital with wire breakages. However there were incidences of bond failures with both the types of retainers in this study. Amongst the two retainers there was more bond failures reported with the conventional lingual retainer than the 3D printed retainer.

There are no studies that compare the long term results of bonding the customized 3D printed Lingual Retainer indicating the scope for studies evaluating the long term effects on the periodontal health, stability and failure rates of the same.

V. CONCLUSION

Maintaining periodontal health is easier with the 3D Printed Retainer. The Conventional Retainer shows significant Plaque accumulation, greater Incidence of Failure and increased Rate of Relapse when compared to the 3D printed retainer.

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