Original Article

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Dentistry Section

The Effects of In-Office Reconditioning on the Slot Dimensions and Static Frictional Resistance of Stainless Steel Brackets

ROHINI ILURU[1], CHAITANYA NELLORE[2], PRAVEEN KUMAR REDDY KARNATI[3], ASHOK KUMAR THALAPANENI[4], VIJAY BHASKAR MYLA[5], KONDA RAMYASREE[6], MANDAVA PRASAD[7]

ABSTRACT

Introduction: Orthodontists are commonly faced with the decision of what to do with loose brackets, and with inaccurately located brackets that need repositioning during treatment. One solution is to recycle the brackets. The potential effects of reconditioning a bracket are dependent upon many factors which may result in physical changes like alteration in slot tolerance, which may influence sliding mechanics by affecting frictional resistance.

Aim: To study and compare the dimensional changes in the bracket slot width and depth in reconditioned brackets from unused brackets under scanning electronic microscope and to study and compare any consequent effects on the static frictional resistance of stainless steel brackets after reconditioning and in unused brackets.

Materials and Methods: Dentarum manufactured 90 stainless steel central incisors edgewise brackets of size 0.22 X 0.030" inch and 0° tip and 0°angulation were taken. 60 samples for measuring frictional resistance and 30 samples for measuring slot dimensions.

Ortho organizers manufactured stainless steel arch wires 0.019 X 0.025" straight lengths 60 in number were considered for measuring static frictional resistance.

Results: The mean slot width and depth of new brackets were 0.0251" and 0.0471", which exceeded the manufacturers reported nominal size of 0.022" X 0.030", by 0.003" and 0.017". The reconditioned brackets demonstrated a further increase in mean slot width and depth to 0.028" and 0.0518" that is by 0.0035" and 0.0047" which is statistically significant ($p=0.001$, 0.002).

The mean static frictional forces of the reconditioned brackets was nearly similar to that of new brackets that is 0.3167N for reconditioned brackets and 0.2613 N for new brackets.

Conclusion: Although the reconditioning process results in physical changes to bracket structure this does not appear to result in significant effect on ex-vivo static frictional resistance.

Keywords: Bracket dimensions, Recycling, Sloth depth, Slot width

INTRODUCTION

Orthodontists commonly encounter problems with debonded brackets and inaccurately positioned brackets, which needs to be repositioned during treatment [1]. Many factors influence the retentiveness of the bracket, frequently due to the action of excess occlusal forces, less retentiveness of certain bracket bases contributing to certain drawbacks like stress, prolonged treatment duration and economic disadvantage.

One solution is to recycle the brackets. Recycling consists basically removal of the remnant bonding agent from the bracket bases, making used bracket amenable for reutilization, without damages to retention mesh, keeping the retentive features intact. However, the efficiency of the orthodontic treatment will be affected by any change in slot size, reduction in bond strength and distortion of the bracket base produced during the reconditioning process. As a result when brackets are recycled, the method used should completely remove the bonding material from the bracket without distorting the bracket [2].

Reconditioning of orthodontic brackets on economic grounds had been a myriad, in clinical practice, for its infection risk between patients and without affecting the bracket performance [3-6]. The in-office reconditioning methods that were advocated are mechanical methods (e.g. Hand piece and rotary burs, chair side sandblasting), thermal methods (e.g. direct flaming, heating in a furnace), and combination of both mechanical and thermal methods (e.g. direct flaming of the bracket base followed by sand blasting and electro polishing – Buchman method) [2].

The potential effects of reconditioning a bracket are dependent upon the type of process used, the type of steel from which the bracket is constructed, and the nature of the bracket base. The physical changes included an alteration in slot tolerance, which has potential to influence sliding mechanics by affecting frictional resistance [4].

A number of fixed appliance features, that may contribute to friction have been investigated. These features include bracket material, bracket width, and slot size. Studies have investigated the effects of arch wire material, arch wire size and the interactions of bracket and arch wire angulations and also investigated the effect of ligation force and the state of lubrication of the system [7,8]. Because, frictional resistance is believed to be a dominating factor in determining the force levels required for moving teeth, it is important to evaluate the bracket-wire interface and the force it may produce during sliding mechanics. Hence the following study was conducted with an aim to study and compare the dimensional changes in the bracket slot width and depth in reconditioned brackets from unused brackets under scanning electron microscope and the effects of the static frictional resistance of stainless steel brackets between unused and after reconditioning, with an 0.019 x 0.025 inch stainless steel arch wire.

MATERIALS AND METHODS

This study was conducted in the Department of Orthodontics and Dentofacial Orthopaedics in the year 2012 at Narayana Dental College and Hospital, Nellore. The friction testing and scanning electronic microscopic study were conducted at the Anna University, Chennai, Tamil Nadu in the Departments of Chemistry and Mechanical Engineering respectively.

Materials used for testing static frictional resistance and slot dimensions: A 45 new and 45 reconditioned stainless steel central incisor brackets (Dentarum) of size 0.022 X 0.030" slot dimensions with 0° tip and 0° torque and 60 straight length stainless steel arch wires (Ortho Organizers) of size 0.019 X 0.025" were selected along with the elastomeric modules (Ormco company, Clear 0.120") to secure the arch wire within the bracket slot.

All these samples were coded separately in order to avoid any observer bias. A 30 new brackets and 30 reconditioned brackets were used for testing static frictional resistance and 15 new and 15 old brackets for measuring slot dimensions. Unused Dentarum standard edgewise 0.022 X 0.030" slot dimension SS central incisor brackets with no built in tip and torque were preferred, as used by Dicrson JA et al., [9]. Edgewise brackets with 0°angulation and torque were used in order to avoid the effect of inbuilt torque value on frictional resistance of the bracket and arch wire. This was more correctly attributable to binding rather than true friction. Test sample of reconditioned standard edgewise central incisor brackets were obtained by in-office reconditioning method as suggested by Buchman [2]. New and reconditioned brackets were compared for changes in slot width and depth and static frictional resistance as done by Jones SP et al., [3,4]. The slot width and slot depth of the bonded brackets may become distorted during debonding process. Distortion of edgewise orthodontic brackets was found at microscopic level when squeezed together with pliers or when a shear force is applied with the blades of the debonding pliers or ligature cutters and even with the use of lift off debonding pliers as suggested by Coley Smith, Rock WP and Oliver RG, Pal AD to minimize the debonding failures, brackets were bonded to Polytetrafluoroethylene (PTFE) sheet so that they were easily removed with tweezers to prevent any distortion to the bracket [3,10].

Measuring of slot width and depth was done using scanning electron microscope at X 30 magnification as done by Rupali kapur, Ram S. Nanda, Porntip Verayangura. [7,11].

TESTING STATIC FRICTIONAL RESISTANCE

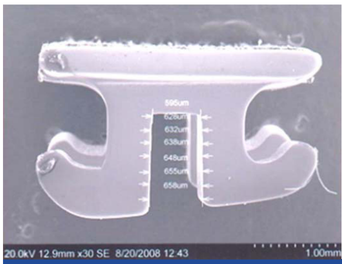
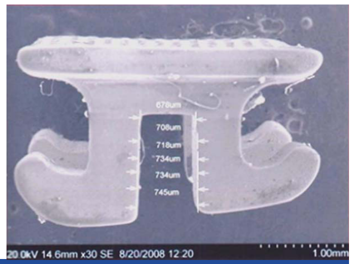
Preparation of Test Sample: Central incisor brackets were used since flat surface of the bracket facilitated mounting of the brackets into a custom made jig used for friction measurement [9]. Experimental brackets were initially bonded to a flat PTEE sheet using a light-cured highly filled orthodontic adhesive, (Enlight light cure adhesive; Ormco Company) in strict accordance with the manufacturer's instructions. The brackets were easily debonded using tweezers. Following bracket debonding, they were subjected to reconditioning process to remove resin layer. The control group was neither bonded initially nor reconditioned.

Reconditioning Method:- Buchman Method [2]

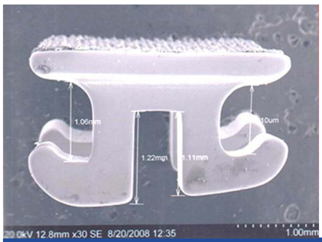
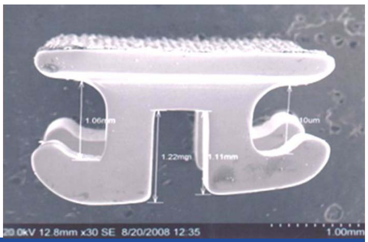
Reconditioning method used for each bracket was, the bracket held with tweezers in Bunsen burner flame for 10 seconds in order to ignite and burn off the bonding agent and immediately quenched in water. Then, a laboratory sandblaster with 50µm aluminum oxide particles was used to sandblast for 5 seconds, after that the brackets were electro polished for 5 minutes.

Measurement of Static Friction: Evaluation of the friction produced at the arch wire – bracket interface was done following a test protocol described by SP Jones et al., [4].

A total of 30 unused brackets and 30 reconditioned brackets were tested against 0.019 x 0.025" diameter stainless steel wire at 0° angulation. Each bracket was mounted on self- curing acrylic block. An acrylic block was prepared from self- cured acrylic in wax pattern. The bracket slot was aligned parallel to horizontal plane by tying bracket slot to a straight piece of 0.021 X 0.025" SS wire prior to mounting. The bracket was then mounted to self- cured acrylic block with cyanoacrylate adhesive. The self-cured acrylic block was fixed with screws into a mounting jig used for friction measurement.

[Table/Fig-1]: Measrement of slot width in unused brackets.
[Table/Fig-2]: Measrement of slot width in reconditioned brackets.

[Table/Fig-3]: Measrement of slot depth of unused brackets.
[Table/Fig-4]: Measrement of slot depth of reconditioned brackets.

Number	Used brackets	Unused brackets
1	0.38N	0.5N
2	0.18N	0.32N
3	0.36N	0.43N
4	0.23N	0.12N
5	0.38N	0.32N
6	0.12N	0.32N
7	0.18N	0.42N
8	0.23N	0.32N
9	0.36N	0.34N
10	0.38N	0.13N
11	0.12N	0.12N
12	0.18N	0.13N
13	0.23N	0.12N
14	0.36N	0.3N
15	0.12N	0.44N
16	0.18N	0.34N
17	0.38N	0.41N
18	0.34N	0.34N
19	0.35N	0.13N
20	0.21N	0.4N
21	0.2N	0.32N
22	0.36N	0.51N
23	0.3N	0.34N
24	0.28N	0.42N
25	0.22N	0.2N
26	0.33N	0.4N
27	0.26N	0.13N
28	0.12N	0.35N
29	0.18N	0.44N
30	0.38N	0.13N

[Table/Fig-5]: Measrement of static frictioal resistance.

Measurement of Slot Dimensions: Hitachi-S-3304 SEM at an operating voltage of 10 kV. Scanning electron microscopy.

The sample of 15 unused and 15 reconditioned brackets were mounted with their sides uppermost on stub of scanning electron microscope, Hitachi-S-3304, at an operating voltage of 10 Kv. This permitted the slot to be viewed from end-on such that both the occluso- gingival slot width and slot depth could be measured

Number	Unused brackets		Recycled Brackets	
	Slot depth	Slot width	Slot depth	Slot width
1	1.205mm	1.648mm	1.26mm	1.703mm
2	1.165mm	1.630mm	1.335mm	1.705mm
3	1.18mm	1.633mm	1.35mm	1.714mm
4	1.185mm	1.620mm	1.26mm	1.723mm
5	1.121mm	1.648mm	1.26mm	1.716mm
6	1.165mm	1.619mm	1.29mm	1.719mm
7	1.18mm	1.626mm	1.26mm	1.714mm
8	1.165mm	1.629mm	1.26mm	1.723mm
9	1.21mm	1.609mm	1.35mm	1.716mm
10	1.165mm	1.647mm	1.335mm	1.716mm
11	1.18mm	1.633mm	1.29mm	1.705mm
12	1.156mm	1.625mm	1.29mm	1.719mm
13	1.165mm	1.625mm	1.26mm	1.721mm
14	1.18mm	1.626mm	1.35mm	1.725mm
15	1.165mm	1.630mm	1.29mm	1.716mm

[Table/Fig-6]: Slot dimension measurements obtoed with SEM (mm).

Bracket	Angulation	Mean	Standard deviation	Degrees of freedom	Standard error	95% Confidence interval	t-value	p-value
Unused	0 degree	0.2613	0.0960	58	0.0175	0.2255-0.2972	1.9058	0.0616
Reconditioned	0 degree	0.3167	0.1238		0.0231	0.2672-0.3575		

[Table/Fig-7]: Static frictional resistance for unused and reconditioned brackets.

without moving the bracket. The brackets were viewed under scanning electron microscope at a magnification of x30, displayed on computer screen, which permitted direct linear measurements to be taken. Slot width was measured as an average of, at three points from bottom of the slot to the surface for unused brackets [Table/Fig-1] and for reconditioned brackets [Table/Fig-2]. Slot depth was measured at occlusal tie wing and gingival tie wing both at the mesial surface and distal surface and average is taken as slot depth for unused brackets [Table/Fig-3] and for reconditioned brackets [Table/Fig-4].

STATISTICAL ANALYSIS

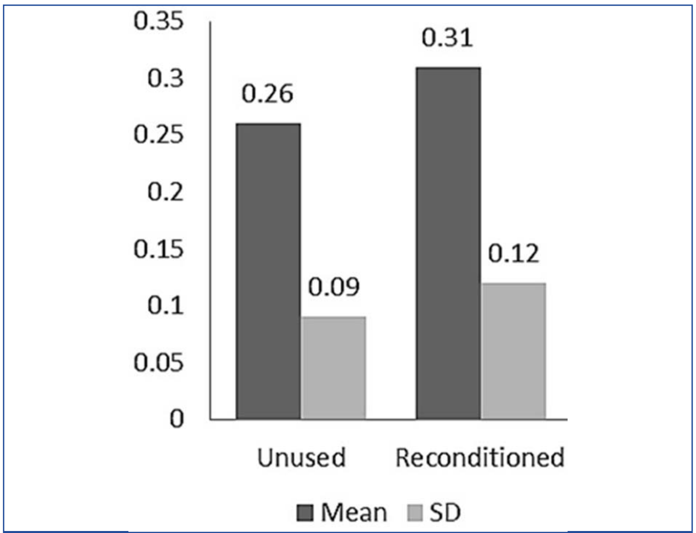
Descriptive statistics, including the mean, standard deviation were calculated for each test group. Student t-test was used to determine whether significant difference existed among the tested groups in static friction and for slot dimensions – slot width and slot depth between unused and reconditioned brackets after SEM study.

The significant differences for all statistical tests were predetermined at p-value < 0.05.

RESULTS

SEM study was conducted to evaluate the changes in slot width and slot depth of new and reconditioned brackets. The values obtained by measuring the static frictional resistance of 60 central incisor brackets were shown in [Table/Fig-5] and the values obtained by measuring slot dimensions with SEM were tabulated in [Table/Fig-6].

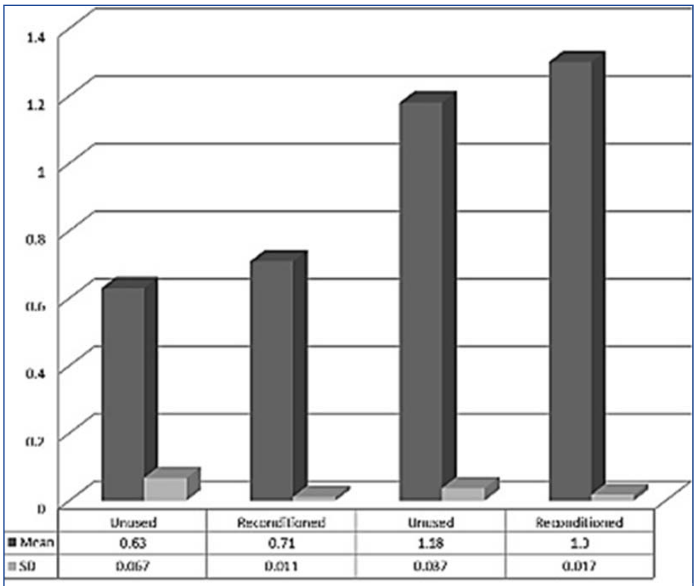
Static frictional resistance for unused and reconditioned brackets: The values obtained through testing of static frictional resistance of stainless steel brackets and arch wire show lower values for unused brackets than that of reconditioned brackets. The mean static friction of unused brackets was 0.2613 where as that of reconditioned brackets was 0.3167. The difference between these two mean values was not statistically significant with a p-value of 0.0616 which is less than 0.05. The values obtained through testing of static frictional resistance are summarized in [Table/Fig-7,8].



[Table/Fig-8]: Mean and standard deviation for static frictional resistance of unused and reconditioned brackets.

	Bracket	Mean (mm)	Standard Deviation	Degrees of freedom	95% confidence Interval	t-value	p-value
Slot Width	Unused	0.630	0.06758	28	06238-0.6360	25.704	0.002
	Reconditioned	0.716	0.0102		0.7118-0.7194		
Slot Depth	Unused	1.18	0.03752	28	1.275-1.317	11.5	0.001
	Reconditioned	1.30	0.0176		1.169-1.188		

[Table/Fig-9]: The values obtained through the SEM study for slot depth.
p = 0.001



[Table/Fig-10]: Mean and Standard deviation for Slot width and Slot depth of unused and reconditioned brackets.

Slot width for new and reconditioned brackets: The values obtained through the SEM study for slot width showed increased values for reconditioned brackets than for reconditioned brackets. The mean slot width for unused bracket was 0.0630 and that of reconditioned bracket was 0.716. The difference between these two values is statistically significant with a p-value of 0.002. The values obtained are summarized in [Table/Fig-9,10].

Slot depth for new and reconditioned brackets: The values obtained through the SEM study for slot depth showed increased values for reconditioned brackets than for unused brackets.

The mean slot width for unused bracket was 1.18 and that of reconditioned bracket was 1.30. The difference between two values is statistically significant with a p-value of 0.001. The values obtained are summarized in [Table/Fig-9,10].

DISCUSSION

Measuring of slot width and depth was done using SEM as done by Rupali Kapur, Ram S. Nanda [7]. The mean slot width of new brackets was 0.0251" (0.629 mm), which exceeded the manufacturers reported nominal size of 0.022", by .003". This is in agreement with the findings of Jones SP, Nidhi B, Verayangkura P, Sebanc J, Basudan AM [4,8,11-13]. The reconditioned brackets demonstrated a further increase in mean slot width to 0.028"(0.0715mm) that is by 0.0035". This correlates with Matasa, Jones SP et al., which is statistically significant (p=0.001) [4,5,8].

The increase in slot width in reconditioned brackets was resulted from reconditioning process and electro polishing in particular, removes metal from all surfaces but more from tie wings and less from the floor of the slot. This is shown when observed under scanning electron microscope as increase in slot width more at the surface of the bracket than at the bottom of slot. This is in line with the findings of Buchman and Matasa [2,5] who concluded that, in agreement with the laws of electro deposition, the maximum metal loss with electro polishing was exhibited on protuberances than on recessed areas. Thus, power arms, wings, tie wings, and edges would be thinned while there was only a minor change in slot dimensions. Furthermore, Buchman's [2] studies showed that the change in slot width in used brackets was less than 20% which appeared that the amount of the change is of little significance.

The mean slot depth of new brackets is 0.0471" (1.1784 mm), which significantly exceeded the manufacturer's nominal depth of 0.030" that is by 0.017". This is also in agreement with Jones SP, Porntip Verayangkura, Sebanc et al., Aisha M. Basudan [4,8,11-13]. The reconditioned brackets showed further increase in slot depth to 0.0518" (1.296mm) that is by 0.0047", This is in agreement with Jones SP, Matasa CG, which is statistically significant (p=0.002) [4,5].

Jones et al., concluded that the reconditioning process resulted in metal removal and slot enlargement [4]. However, the clinical significance of this result was still questioned. Removal of bonding agent, which is usually a type of thermo filling resin, is the most critical part of the recycling process and requires long exposure to heat. This is accompanied by sandblasting and electro polishing procedures. For complete decomposition of bonding agent to occur when heat is used, the temperature of the process would likely be in the sensitization if not the heat softening range of the metal [14].

Exposure to heat may lead to stress relieving or softening of cold worked metal along with decreasing its corrosion resistance. At the same time, this may produce a layer of metal oxide or scale on metallic surface, which would have to be removed by electro polishing, thus leading to a possible slot widening in a bracket [2,8,14].

Measurement of Static Frictional Resistance: The static frictional forces were selected to evaluate in this study rather than kinetic frictional forces because tooth movement along an archwire occurs in very short steps rather than in continuous motion which is suggested by SP Jones, Porntip Verayangkura et al., [4,11]. Static Friction was considered to have a greater effect on the mechanics than kinetic friction, as initially static frictional resistance between bracket and archwire must be overcome in order to initiate tooth movement, once movement has been initiated, kinetic frictional resistance must overcome in order to maintain constant movement James R Bender et al., [15]. The cross head speed of Instron in this study was set at 0.5mm/min, since the study of Kusy et al., had showed that from 0.0005 to10 min/mm, the coefficient of friction for stainless steel archwires was unaffected [16].

The method of ligation was another important factor to determine the occurrence of frictional force. It has been shown that increased ligation force gives increased frictional resistance. In the study Paola Gandini and Hain et al., stated that the loosely tied stainless steel ligatures offer the lowest frictional resistance when compared to other methods (super-slick module, elastomeric module and light ligature wire) [17,18]. Consistent ligation forces are difficult to attain with SS ligatures even for trained operators in order to control the ligation force that may affect the static frictional force, Iwaski et al., [19]. In this study, the elastomeric modules (colors, Ormco company clear 0.120") were selected.

Artificial saliva was used for lubrication of SS brackets and archwires. There have been several reports showing that the friction increases in the presence of saliva. Porntip Veryangkura and Baker showed reduction of friction between 15-19% [11,20]. In a study by Andreasen and Quevedo [21], they stated that the effect of saliva was insignificant.

The mean static frictional forces of the reconditioned brackets was nearly similar to that of new brackets that is mean 0.3167 N for reconditioned brackets and 0.2613 N for new brackets, with p-value of 0.0616, which says there was no statistically significant difference in the mean static friction between the new and the reconditioned brackets. This was in agreement with Jones et al., [4] whose findings showed that when the mean static frictional resistance of the new and the reconditioned brackets was compared, there were no statistically significant differences attributed to the reconditioning process.

The effects of increase in slot width in reconditioned brackets did not result in static frictional force reduction. Andreasen et al., had reported an insignificant effect of the bracket width on bracket arch wire friction, [21] where as other investigators like Frank and Nikolai showed that an increase in friction with increased bracket width [22]. Although, it might have been expected that the smoothing effects of sliding wear of the slot base resulting with the effects of electro polishing by the reconditioning process, would have produced a reduction in frictional resistance, this was not demonstrated by this study.

Furthermore, it has been suggested by kusy et al., that a low surface roughness may not always be a major factor in reducing frictional resistance [23,24]. Similarly, the electro polishing phase of reconditioning may have resulted in minimal effects, since previous work suggested that the process appears to exhibit greater effects on bracket protuberances and lesser effects on the slot base (Buchmann) [2].

LIMITATIONS

As this is an invitro study, and limited to certain isolated procedures for testing, the results cannot be impressive. The same study can also be tried with other methods of debonding or with clinically debonded brackets, reconditioning and testing for frictional resistance for more precise results.

CONCLUSION

Despite of changes in slot dimensions there was no statistically significant difference in static frictional resistance between new unused and reconditioned brackets when compared at 0° angulations.

Although the reconditioning process results in physical changes to bracket structure, including increase in bracket slot tolerance, this does not appear to result in significant effect on ex-vivo static frictional resistance.

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PARTICULARS OF CONTRIBUTORS:
1. Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Narayana Dental College and Hospital, Chinthareddypalem, Nellore, Andhra Pradesh, India.
2. Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Narayana Dental College and Hospital, Chinthareddypalem, Nellore, Andhra Pradesh, India.
3. Reader, Department of Orthodontics and Dentofacial Orthopedics, Narayana Dental College and Hospital, Chinthareddypalem, Nellore, Andhra Pradesh, India.
4. Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, Al Badar Rural Dental College and Hospital, Gulbarga, Karnataka, India.
5. Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, St. Joseph Dental College and Hospital, Duggirala, Eluru, Andhra Pradesh, India.
6. Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Narayana Dental College and Hospital, Chinthareddypalem, Nellore, Andhra Pradesh, India.
7. Professor and Head, Department of Orthodontics and Dentofacial Orthopedics, Narayana Dental College and Hospital, Chinthareddypalem, Nellore, Andhra Pradesh, India.

NAME, ADDRESS, E-MAIL ID OF THE CORRESPONDING AUTHOR:
Dr. Rohini Iluru,
Senior Lecturer, Department of Orthodontics and Dentofacial Orthopedics, Narayana Dental College and Hospital,
Chinthareddypalem, Nellore, Andhra Pradesh, India.
E-mail : dr.rohiniiluru23@gmail.com

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