Original Article

A comparative evaluation of fatigue resistance of two different implant overdenture stud attachments with two different denture base materials: An *in vitro* study

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Abstract

Introduction: The two implant-supported overdentures have overcome the retention and stability-related problems of conventional mandibular denture. Stud attachments are widely available, less expensive, and easy to use.

Aims and Objectives: To determine fatigue resistance of two different stud attachments with two denture base materials – autopolymerizing and heat cure acrylic resin till 4320 cycles simulating 03 years of service.

Materials and Methods: Stud implant overdenture attachments, i.e., ball and socket and Dalla Bona attachments were tightened over the implants in two different mandibular edentulous base models. The housings were incorporated with both direct (chairside) and indirect (laboratory) technique into conventional mandibular dentures. These overdentures were subjected to continuous removal and insertion on Universal Testing Machine till 4320 cycles simulating 3 years of service assuming that patient takes out denture, 4 times in a day. The fatigue resistance was calculated for 0, 1440 (1 year), 2800 (2 years), and 4320 (3 years) cycles. Unpaired and paired *t*-tests were applied to find the level of significance.

Results: Ball and socket attachments housed with heat cure acrylic resin (indirect technique) had the highest values of fatigue resistance at all cycles. Following were Dalla Bona attachments with autopolymerizing acrylic resin (direct technique), ball and socket attachments with autopolymerizing acrylic resin (direct technique), and Dalla Bona attachments with heat cure acrylic resin (indirect technique) as per statistical analysis.

Conclusion: Two implant-supported mandibular overdenture with ball and socket attachments incorporated by indirect technique showed higher values in terms of retention and absence of disengagement/fracture of components.

Keywords: Ball and socket attachments, Dalla Bona attachments, fatigue resistance, implant-supported overdenture, overdenture stud attachments

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INTRODUCTION

The residual ridge resorption challenges the success of mandibular complete denture retention.[1] The treatment of edentulous mandible with the two implant-supported overdenture is a well-accepted treatment with long-term successful outcomes for prosthesis and implants[2] and now considered to be the standard of care of treatment.[3-5]

Van Steenberghe *et al*.[6] were among the first authors to propose placement of 2 implants in the edentulous mandible in 1987. Their 98% success rate, with up to 52 months of observation, was encouraging. The prosthesis survival rates for 2 implants ranges from 92% to 100%, as per recent studies.[7,8]

Stud, ball, and conventional bar attachments are the commonly used systems in implant-supported overdentures and their efficacy is scientifically supported.[9-13] Stud attachments are very straightforward to use and provide reasonable retention and stability for implant overdentures.[14] Among stud attachments, ball and socket, Dalla Bona, and locators are frequently used. Ball attachments have metal as matrix and silicone/nylon cap as patrix whereas Dalla Bona have both matrix and patrix as metals. The combination of materials such as a metal–nylon or metal–metal contact might show differences in respect to surface wear and decrease in resistance with repetitive removal–insertion cycles.[15,16]

Therefore, it is required to know which material houses well with which type of overdenture attachment for longevity of the complete denture prosthesis and reduce failure of prosthesis in turn decreasing the patients' visits. Hence, this study was undertaken with the aim to determine the fatigue resistance of two different stud overdenture attachments – ball and socket and Dalla Bona attachments with different denture base materials – autopolymerizing and heat cure acrylic resin, in two implant-supported mandibular overdenture by process of continuous insertion and removal upto 4320 cycles. The null hypothesis was that there will be no difference in the fatigue resistance between ball and socket and Dalla Bona attachments, by direct (H0) and indirect method (H1).

MATERIALS AND METHODS

Mandibular edentulous base Models 1 and 2 were made by using Heat cure acrylic resin - Clear (DPI Heat Cure Universal Pack–Clear) with equidistant implants from midline at B and D positions. The two Ball attachments (ARDS implants) and two Dalla Bona (Marketed by Lifecare Devices Pvt. Ltd, Mumbai) were tightened over the implants in Model 1 and 2, respectively, with torque wrench at 30 N/cm.

Fabrication of mandibular denture

Twelve mandibular dentures were made with Heat cure acrylic resin (SR Triplex Hot Acrylic Resin, Ivoclar Vivadent Inc.) by conventional procedure, for incorporation of housings and fit was checked over Model 1 and 2.

Transfer of housings to denture

Direct technique

The access openings were made on the lingual flange of mandibular denture near canine region to allow visualization of the attachments under the denture base and excess material to flow. The uniform space must be existed in the intaglio surface of denture to house both metal and silicone components. The autopolymerizing acrylic resin monomer and polymer were mixed in rubber cup in flowable consistency. The attachments were coated with mixed acrylic resin, and a thin layer of resin was painted over opposing surface in the intaglio surface of denture. The mandibular denture was seated over the respective model and held firmly till it completely polymerized. After the final set, the denture was lifted up slowly and the female housings got transferred to the intaglio surface of denture [Figures 1 and 2]. The excess was trimmed, polished, and finished. Care was taken to avoid any voids around the housings. The fit of mandibular dentures was reevaluated on their respective Models 1 and 2, after transferring of female housings [Figures 3 and 4]. By this procedure, six mandibular overdentures, namely, AB1, AB2, and AB3 for Model 1 and AD1, AD2, and AD3 for Model 2, were prepared by direct technique for both types of attachments where A stands for autopolymerizing acrylic resin, B stands for ball attachments, and D stands for Dalla Bona attachments.

Indirect technique

The final impressions of Model 1 and 2 were made with stock trays. Light-body impression material (Virtual Light Body PVS, Ivoclar Vivadent) was injected around the male components. Then, heavy-body impression material (Virtual Putty Regular Set, Ivoclar Vivadent) in the stock tray was placed over the model and allowed it to set simultaneously with the light-body material. The two implant analog arrows (Alphbio, Germany) for Ball attachments and two brass analogs (Marketed by Life Care Devices Pvt. Ltd) for Dalla Bona were secured properly over the impressions [Figures 5 and 6] and poured with die stone (Kalrock, Kalabhai, India) for master casts. The occlusion rims were made over record bases made with autopolymerizing acrylic resin (DPI RR Cold cure), and

Figure 1: Mandibular overdenture with nylon housings of ball attachments transferred to intaglio surface by direct technique

Figure 2: Mandibular overdenture with metal housings of Dalla Bona transferred to intaglio surface by direct technique

Figure 3: Mandibular overdenture over the Model 1 after direct technique

Figure 4: Mandibular overdenture over the Model 2 after direct technique

Figure 5: Closed tray impression with implant analog arrows for ball attachments

Figure 6: Closed tray impression with brass laboratory analogs for Dalla Bona attachments

teeth arrangements (Acryrock) were done. Flasking and then dewaxing was carried out in usual manner.

After dewaxing, the female housings of respective models of ball attachments and Dalla Bona attachments were

snapped on, over the analogs. Heat cure acrylic resin (SR Triplex Hot Acrylic Resin, Ivoclar Vivadent Inc.) was mixed as per the instructions, and mixed dough was put over both the teeth surface and housings. Then, the dentures were processed as conventional denture. The dentures with transferred housings were finished and polished [Figures 7 and 8] and checked for fit over their respective models [Figures 9 and 10]. The six mandibular overdentures were made by indirect technique and named as HB1, HB2, and HB3 and HD1, HD2, and HD3 where H stands for heat cure acrylic resin, B stands for ball and socket attachments, and D stands for Dalla Bona attachments.

Testing of fatigue resistance of both the attachment systems fabricated on the models was carried on the Universal Testing Machine (UTM Uni Test-10, ACME Engineer, India, 2015) [Figure 11]. Dislodging forces were applied in a vertical direction at a speed of 5 mm/min, on the center of mandibular overdenture with base clamped tightly on the UTM. Load cell of 100 kg was selected. The readings of all samples of both attachment systems (AB1, AB2, AB3, HB1, HB2, HB3, AD1, AD2, AD3, HD1, HD2, HD3) were noted at 0, 1440, 2880, and 4320 cycles to check for the loss of retention and development of fatigue.

The readings at 0 cycles were an initial reading denoting maximal value of retention. After subjecting to 1440 cycles, the retention values were noted with a force gauge that measured the force required to dislodge the dentures placed on the models which were clamped onto the universal testing assembly. Similarly, the retention values were obtained at 2880 and 4320 cycles.

RESULTS

The intergroup comparison that is to compare ball and socket attachments and Dalla Bona attachments relined with autopolymerizing acrylic resin and with heat cure acrylic resin were analyzed by unpaired *t*-tests.

The fatigue resistance of ball and socket attachments and Dalla Bona attachments relined with autopolymerizing acrylic resin, i.e., by direct technique (AB and AD); when compared [Graph 1], statistically no significant difference in values were found at any cycle. The mean fatigue resistance at 0 cycle of AB group was 35.15 ± 4.91 N and AD group was 34.35 ± 4.54 N, whereas by 4320 cycles, it was reduced to 17.45 ± 7.81 N and 10.05 ± 0.20 N, respectively [Table 1].

Figure 7: Mandibular over denture with transferred nylon housings of ball attachments by indirect technique

Figure 8: Mandibular overdenture with transferred metal housings of Dalla Bona attachments by indirect technique

Figure 9: Mandibular overdenture over the Model 1 after indirect technique

However, significant difference was found at all cycles with fatigue resistance of ball and socket attachments and Dalla

Figure 10: Mandibular overdenture over the Model 2 after indirect technique

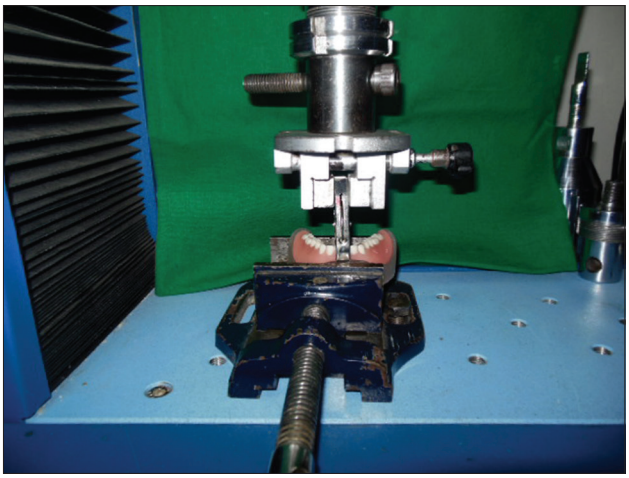
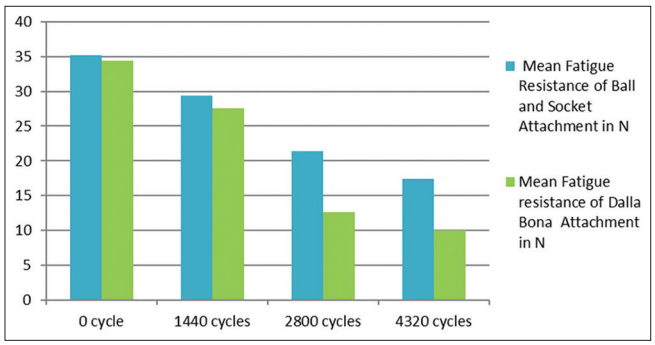
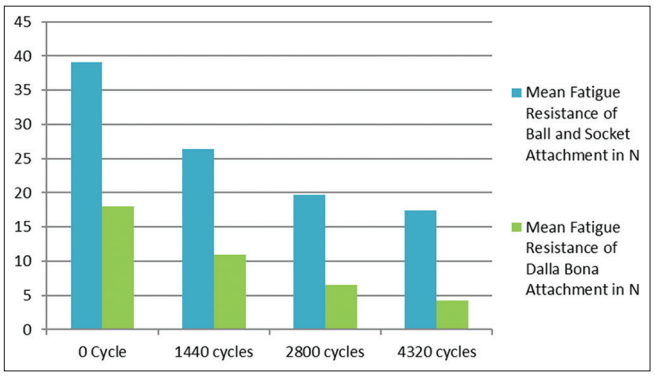


Figure 11: Sample clamped on platform and being tested on Universal Testing Machine



Graph 1: Comparison of mean fatigue resistance (*n*) by direct method between ball and socket attachment and Dalla Bona attachment at all cycles



Graph 2: Comparison of mean fatigue resistance (N) by indirect method between ball and socket attachment and Dalla Bona attachment at all cycles

Bona attachments when secured with heat cure acrylic resin, i.e., indirect technique (HB and HD) [Graph 2]. The mean value of HB group was 39.15 ± 0.23 N and HD group being 17.97 ± 8.88 N at 0 cycle. After subjecting HB and HD group to 4320 cycles, the mean values were 17.42 ± 2.53 N and 4.25 ± 2.02 N [Table 2].

The intragroup comparison was done by paired *t*-test. Ball and socket attachments relined with autopolymerizing acrylic resin, i.e., by direct technique (AB1, AB2, AB3); when compared from 0 cycle to 1440, 2800 and 4320 cycles, statistically no significant difference was found at any cycle [Graph 3]. However, by indirect technique (HB1, HB2, HB3), statistically significant difference was found at all cycles with p values at 0–1440 cycle = 0.038, 0–2800 cycles = 0.003, and 0–4320 cycle = 0.004 ($P < 0.005$) [Graph 4].

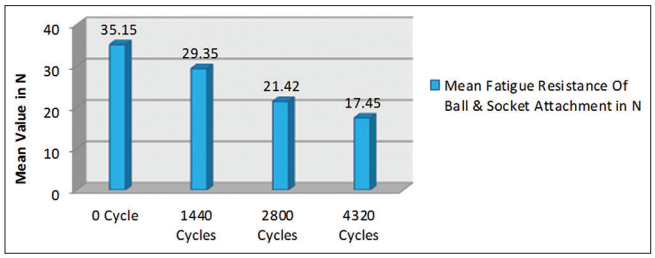
In Dalla Bona attachments relined with autopolymerizing acrylic resin, i.e., direct technique (AD1, AD2, AD3), statistically no significant difference was found at 0–1440 cycles but significant difference was found at 0–2800 cycles ($P = 0.015$) and 0–4320 cycles ($P = 0.010$) [Graph 5]. In HD Group (HD1, HD2, HD3), i.e., by indirect technique, statistically no significant difference was found at any cycle [Graph 6].

DISCUSSION

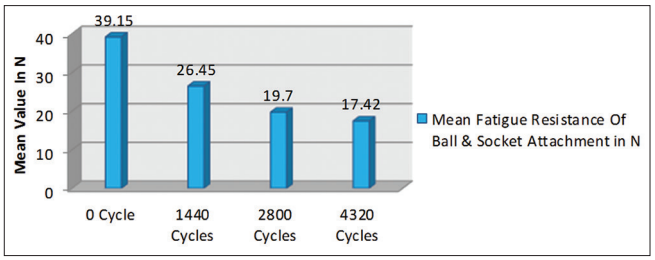
The concept of overdentures originally involved fixing mechanical attachments to teeth, roots, or dental implants to enhance retention and stability of conventional dentures.[17,18]

The basic principle in employing overdenture attachment systems in the treatment of resorbed edentulous mandible is to increase denture retention and stability, thereby enhancing chewing efficiency as well as patient comfort and compliance.[19,20]

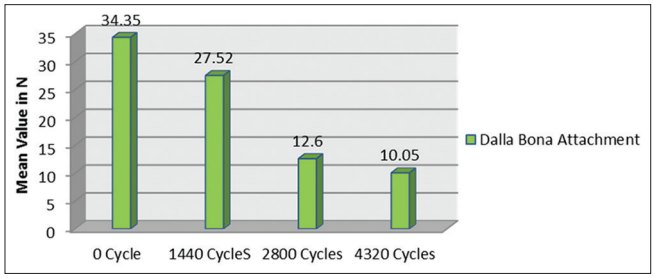
With time and use, these attachments wear down[21] and have adhesive or fatigue failure with male components of attachment, due to repeated cycles.



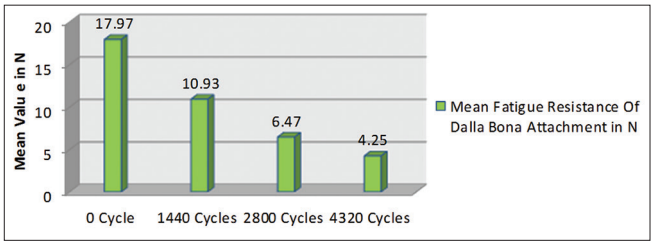
Graph 3: Comparison of direct method for mean fatigue resistance (*n*) within the ball and socket attachment Group (AB) (*n* = 3)



Graph 4: Comparison of indirect method for mean fatigue resistance (*n*) within the ball and socket attachment Group (HB) (*n* = 3)



Graph 5: Comparison of direct method for mean fatigue resistance (*n*) within the Dalla Bona attachment Group (AD) (*n* = 3)



Graph 6: Comparison of indirect method for mean fatigue resistance (*n*) within the Dalla Bona attachment Group (HD) (*n* = 3)

Table 1: Comparison of direct method for mean fatigue resistance between the two groups – ball and socket and Dalla Bona attachments (AB and AD) at all cycles (*n*=6)

Samples	Cycle	Mean±SD		*t*	*P*
		Ball and socket attachment	Dalla Bona attachment		
AB and AD	0	35.15±4.91	34.35±4.54	0.21, df=4	0.846, nonsignificant
	1440	29.35±5.30	27.52±6.98	0.36, df=4	0.735, nonsignificant
	2800	21.4±12.0	12.60±1.49	1.26, df=4	0.276, nonsignificant
	4320	17.45±7.81	10.05±0.20	1.64, df=4	0.176, nonsignificant

SD: Standard deviation

Table 2: Comparison of indirect method for mean fatigue resistance between the two groups – ball and socket and Dalla Bona attachments (HB and HD) at all cycles (*n*=6)

Samples	Cycle	Mean±SD		*t*	*P*
		Ball and socket attachment	Dalla Bona attachment		
HB and HD	0	39.15±0.23	17.97±8.88	4.13, df=4	0.014*
	1440	26.45±4.23	10.93±4.62	4.29, df=4	0.013*
	2800	19.70±1.72	6.47±2.50	7.55, df=4	0.002*
	4320	17.42±2.53	4.25±2.02	7.04, df=4	0.002*

*Significant. SD: Standard deviation

This study was designed to investigate the effect of removal and insertion of mandibular two implant-supported overdenture in loss of retention of two different stud overdenture attachments for up to 4320 cycles.

Based on the results of study by Al Ghafli *et al*.,[22] two implants were placed parallel to each other and perpendicular to the horizontal plane to retain its retentive capacity for a longer period of time in our study.

There are various techniques for incorporating these attachments to the overdenture. Broadly, they can be classified as direct techniques (performed by the clinician intraorally) or indirect techniques (performed by the technician in the laboratory).[23]

Nissan *et al*.[24] stated that the direct technique for attachment incorporation into mandibular implant-supported overdentures using ball attachments was superior to the indirect technique from the aftercare perspective in both immediate (pressure sores) and long-term (liner and attachment replacement). Dominici *et al*[25] also supported direct procedure as it eliminated lengthy indirect laboratory procedure that requires additional implant components such as impression posts and transfer analogs. Taddei *et al*., 2004[26] also favored the direct technique for locating a ball attachment intraorally for being simple, economic, quick and allows the patient to retain the prosthesis.

The disadvantages of the direct technique included necessity for blocking out all undercuts during the clinical procedure, the retentive caps might not hold if free monomer present, and shrinkage, water sorption, and voids within the autopolymerizing resin.[27]

Bidra *et al*.[28] illustrated different techniques of incorporation of attachments to housings and concluded that depending on the clinical situation, incorporating

overdenture attachments can either be performed at the record base stage, denture processing stage, or denture insertion stage.

Our study design included evaluation of two different overdenture attachments, namely, ball and socket and Dalla Bona attachments housed with two different materials, i.e., autopolymerizing acrylic (direct technique) and heat cure acrylic resin (indirect technique).

This being an *in vitro* study and assuming that the patient takes out mandibular denture 04 times in a day, the removal and insertion cycles were repeated till 4320 cycles simulating 03 years of clinical service, and thus, the fatigue resistance was compared at different cycles, i.e., 0 cycle (first removal), 1440 cycle (1 year of use), 2800 (2 years of use), and 4320 (3 years of use) to assess their clinical performance. The methodology utilized in this study follows that of Saito *et al*.[29] and Guttal *et al*.[30]

The most common mechanical complication as mentioned in a review article by Goodacre *et al*.[31] in their order of reported frequency was overdenture loss of retention/adjustment (30%). As supported by many authors, Johns *et al*.,[32] Hemmings *et al*.[33] and Allen *et al*.,[34] it was found that relining was required in significant number of overdenture patients, and loss of retention of mandibular overdenture was a significant problem.

Being the most common complication, our objective of the study was to find which overdenture attachment houses well with which denture base material so that loss of retention can be minimized, minimizing patient's dissatisfaction.

The Universal Testing Machine (UTM ACME Engineers) was used to perform our tests. The resulted fatigue resistance values ranged from approximately 4–40 N. However, the values decreased with increased number of cycles where the highest value obtained was 39.55 N (approximately 40 N) at 0 cycle. Our values were in accordance with a study by Setz *et al*.[35] in which ball and magnet attachments were compared till 15000 cycles. Retentive forces ranged between 3 and 85 N when retained by two implants. They assumed that forces of 20 N was sufficient for overdentures in edentulous mandible which was also proposed by Daou *et al*.[36] Repeated cyclic loading eventually constitutes a mechanical deterioration and progressive deformation leading to loss of retention, as done in our study.

In an *in vitro* study by Besimo *et al*.,[37] different types of attachments such as spherical anchor by Dalla Bona, cylindrical anchor by Dalla Bona, Conod, and Gerber attachment were evaluated and reported that the retention strengths between 5-8 N may be sufficient.

In a study by Gamborena *et al*.,[38] retention value was tested with different color-coded nylon plastic attachments of ERA attachment systems implicating that different material composition exhibited changes in the retention force. After a simulated 3 years of attachment placement and removal up to 5500 cycles, there was an overall retention loss ranging from 85% to 88%. In our study, rate of retention loss with ball and socket attachments was approximately 50% and 30% for Dalla bona, for over a period of 3 years. This can be attributed to the difference in housing materials as ball and socket attachments had nylon housings which may get deformed and Dalla Bona had metal housings which were quite rigid. The mechanism involved in the nylon surface loss seemed to be gross surface deformation and cohesive failure, resulting in significant deterioration rather than those totally made up of noble metals.[39]

Our analysis revealed that ball attachments produced higher levels of retention followed by Dalla Bona attachments. This result is also in accordance with a study by Shastry *et al*.[40] where the ball/o-ring and bar and clip attachments exhibited higher retentive capacities than the Locator® attachment over time.

The results of our study indicated that the different denture base materials such as autopolymerizing acrylic resin and heat cure acrylic resin used to house overdenture components to two different stud attachments, i.e., ball and socket attachments and Dalla Bona attachments, in two implant-supported mandibular overdenture had significant difference in values of fatigue resistance at cycles up to 4320, when indirect method was used; thus, the null hypothesis (H1) was rejected. Besides, since no statistically significant difference was found in both the attachments when relined using direct method, the null hypothesis (H0) was accepted

Limitation of the most *in vitro* fatigue studies is dry testing environment. Future research should develop such in vitro settings that can better replicate stresses occurring on attachments under function in an environment that simulates the oral cavity. The testing with more specimens would allow for more powerful results to be obtained.

CONCLUSION

Through our results and statistical analysis, following conclusions could be made:

1. Ball and socket attachments and Dalla Bona attachments when housed by direct technique, no

significant difference was found at any cycle. However, with indirect technique, significant values were obtained.

2. The ball and socket attachments relined with autopolymerizing acrylic resin showed no significant difference when compared with other two samples, from 0 cycle to 4320 cycles. However, with indirect method, significant results were obtained at all cycles.
3. The Dalla Bona attachments had lesser initial values of retention as compared to ball and socket attachments. However, there was a significant difference in Dalla Bona attachments relined with autopolymerizing acrylic resin using direct method.
4. The Dalla Bona attachments housed by indirect technique had the least value of initial retention. Besides, no significant differences in values were found in any cycle.
5. No fracture or removal of any component was found.

In short, the order of preference in selecting overdenture attachments in terms of fatigue resistance can be as follows:

Ball and socket attachments with heat cure acrylic resin (indirect method) > Dalla Bona attachments with autopolymerizing acrylic resin (direct method) > Ball and socket attachments with autopolymerizing acrylic resin (direct method) > Dalla Bona attachments with heat cure acrylic resin (indirect method).

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Conflicts of interest
There are no conflicts of interest.

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