

EVALUATION OF FRACTURE RESISTANCE OF TWO LAMINATE VENEERS CERAMIC MATERIALS AT TWO LOADING ANGULATIONS (IN-VITRO STUDY)

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ABSTRACT

Statement of problem; Zirconia reinforced lithium silicate glass-ceramic is considered as a new ceramic material. Although not widely used for the construction of laminate veneers, it would be a promising material regarding the fracture resistance of laminate veneer.

Aim of The Study; to evaluate the Fracture Resistance of laminate veneers constructed with two different ceramic materials (Zirconia reinforced lithium silicate glass ceramic (Celta DUO) and Lithium disilicate glass ceramics (e.max CAD) at different load angulations (60°, 125°).

Methodology; A total of 16 freshly extracted central incisors were mounted in epoxy blocks then prepared with butt joint design, then divided into two equal groups and subgroups Group 1 e.max group (laminate veneers constructed from e.max CAD) /Group 2 Celta duo group (laminate veneers constructed from Celta duo) then each group was subdivided into 2 sub-groups according to loading angle. Group A load angle 60° / Group B load angle 125° Fabricated by CEREC MC XL milling machine. The veneers were fired for a short firing cycles, then cemented with Choice 2 resin cement after surface treatment of both teeth and veneers according to manufacturer instructions. All samples were subjected to thermocycling equivalent to one year of clinical service. Measurements were reported after thermocycling. All samples were subjected to universal testing machine to evaluate the effect of Different load angulations (60°, 125°) on fracture resistance.

Results: The highest fracture resistance mean value was recorded for e.max group with 60° loading angle followed by e.max group with 125° loading angle then Celtra Duo group with 60° loading angle while the lowest fracture resistance mean value was recorded for Celtra Duo group with 125° loading angle According to the ANOVA test), the gap between groups was statistically non-significant.

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Conclusion:

1. Fracture resistance of ceramic veneers under functional Loads was higher at 60° than at 125° angle for both ceramic materials.
2. Both Celtra duo and e. max CAD laminate veneers provide clinically acceptable fracture resistance values.
3. Zirconia reinforced lithium silicate (Celta duo) is a promising material for laminate veneers fabrication.

Clinical implication: Celtra duo is a promising material to be used for laminate veneers constructions in the esthetic region.

KEYWORDS: fracture resistance, E.max CAD, Celtra duo CAD, laminate veneer, ZLS.

INTRODUCTION

The restoring of an unaesthetic anterior tooth has been a constant challenge to all dentists. The need for ceramic laminate veneers to repair unaesthetic teeth has increased due to increased demand and increased patient awareness. However, due to the various stresses that ceramic veneer is exposed to, its durability has often been questioned. Ceramic veneers' long-term prognosis could be influenced by a variety of factors, as well as a thorough case Selection, tooth surface, preparation design, ceramic thickness, laboratory veneer production, cementation material, and functional and parafunctional activities are some of the topics covered.⁽¹⁾

One of the most contentious aspects of the preparation design is its effect on the performance rate. Another significant factor affecting the long-term performance of ceramic veneers is the occlusal load. As a consequence, the path of load application during testing has an effect on the outcome. Numerous studies have been carried out in the past to evaluate the fracture resistance of ceramic veneer materials, but none have linked them to practical movements.⁽¹⁾ A zirconia reinforced lithium silicate glass ceramic for dental CAD/CAM applications has recently been introduced to the market for the manufacturing of inlays, onlays, partial crowns, veneers, anterior and posterior crowns, and anterior and posterior single tooth restorations on implant abutments. This new glass ceramic has a zirconia content of 10%

by weight.⁽²⁾ The aim of this study was to assess the fracture resistance of laminate veneers made from two ceramic materials (e-max CAD and Celtra DUO) at various loading angles, simulating functional movements (125° and 60° representing protrusive and intercuspal movements, respectively).⁽¹⁾

MATERIAL AND METHODS

A total of 16 freshly extracted human upper central incisors teeth were collected of an average similarity in size and shape were selected to be used in this study after Cairo university esthetic committee approval.

All teeth were mounted in epoxy resin blocks; Teeth preparation was done by computer numerically controlled milling machine according to manufacturer instructions. All samples were numbered and randomized into two groups using computer generated random tables by (random.com)

Laminate veneers construction

A CAD/CAM system (Cerec premium 4.4 software) was used for the fabrication of all samples. Scanning was done twice for each tooth; Sound tooth was scanned first to provide a bio generic copy to help in designing the laminate veneer, then prepared tooth was scanned using the CEREC Omnicam.

With the aid of both Cerec software and the biogeneric copy option, the scanned unprepared

tooth was correlated to the preparation in order to construct virtual laminates identical to the tooth form before preparation.

Then designing of the restoration was done using the software considering spacer thickness 80μ , labial thickness 0.7mm and incisal thickness 2 mm to standardize the dimensions of all the laminate veneers.

Milling was done with CEREC (MC XL) 4 – axis milling machine. Both IPS e-max CAD and Celtra duo ceramic laminates were fired in a short firing cycle for 30 minutes at 850°C for e.max and 8 minutes for Celtra duo according to manufacture instructions.

Bonding procedure of veneers: The laminate veneers were cleaned in an ultrasonic cleaner then gently air dried. The internal fitting surfaces of both e max & Celtra duo laminate veneers were treated by 9.5% Hydrofluoric acid for 30 seconds for Celtra duo & 20 seconds for e.max then washed under running water & air dried. A silane coupling agent was scrubbed on the fitting surface gently and air thinned for 1 min according to manufacturer's recommendations. Then 1 coat of bonding agent was applied to fitting surface of the veneer, Then, dried gently for 2-5 seconds without polymerization.

A 37% phosphoric acid was applied for 15 seconds for enamel then rinsed under running water. Gentle air dryness was performed on the etched teeth surfaces. Then, coated with 2 consecutive coats of the single bond adhesive using a micro brush. The veneers were bonded in place with translucent shade of light cured CHOICE 2 veneer luting resin cement. Each laminate was seated on its respective tooth with finger pressure, and excess cement was carefully removed from the margins, using blunt instrument after 2-3 seconds of preliminary light polymerization, and the restorations were then completely light polymerized with an energy density of $480\text{mW}/\text{cm}^2$ for all aspects of the tooth for 30 seconds each, according to manufacturer's instructions

Thermocycling The number of cycles performed was 2000, which corresponded to one year. Each water bath has a 25-second dwell period with a 10-second lag time. The low temperature point was 5°C ., while the high temperature point was 55°C . (3,4)

Mechanical testing of specimens

All samples were individually placed on a computer-controlled material testing machine with a 5 kN load cell, and data was collected using computer software. Screws were tightened to fasten samples to the lowest fixed compartment of the testing machine. Fracture resistance testing was performed using a metallic rod with a round tip (3.4 mm diameter) attached to the upper movable compartment of the testing machine travelling at a cross-head speed of 1mm/min and a compressive mode of load applied at incisal angle (by fixing the sample in specially designed 60° & 125° angle jigs). The load required to fracture was measured in Newtons and exhibited by an audible crack and confirmed by a sharp drop in the load-deflection curve recorded using computer software.



Loading of the tooth at 60° angle.

RESULTS

The data was shown using the mean and standard deviation (SD) of the values. Graph Pad In stat (Graph Pad, Inc.) software for Windows was used to evaluate the findings. A statistically significant value of P 0.05 was used. The student t-test was used for comparison after homogeneity of variance and normal distribution of errors were proven. To determine the influence of each variable, a two-way analysis of variance (ANOVA) was used (materials and loading angle). Each group's sample size (n=8) was sufficient to detect high effect sizes for main effects and pair-wise comparisons, with an acceptable level of power set at 80% and a 95% confidence level.

Fracture resistance

Table (1) analyzes and visually shows descriptive data as a function of material groups and loading angle, including mean values and standard deviation of fracture resistance test results measured in Newton (N).

The highest fracture resistance mean value was recorded for **e.max group** with **60°** loading angle (197.13 \pm 48.5 N) followed by **e.max group** with **125°** loading angle mean value (188.29 \pm 17.89 N) then **Celtra Duo group** with **60°** loading angle mean value (177.81 \pm 27.08 N) while the lowest fracture resistance mean value was recorded for **Celtra Duo group** with **125°** loading angle (166.16 \pm 23.43 N).

According to the ANOVA test ($p=0.4606 > 0.05$), the gap between groups was statistically **non-significant**.

With **e.max group**; it was found that **60°** loading angle subgroup recorded statistically non-significant higher fracture resistance mean value (197.13 \pm 48.5 N) than **125° degree** one (188.29 \pm 17.89 N) as verified by paired t-test ($p = 0.7121 > 0.05$).

With **Celtra Duo group**, it was found that **60°** loading angle subgroup recorded statistically significant higher fracture resistance mean value (177.81 \pm 27.08 N) than **125°** one (166.16 \pm 23.43 N) as proved by paired t-test ($p = 0.4874 > 0.05$)

Comparison between both materials with 60° loading angle. It was found that **e.max group** recorded statistically non-significant higher fracture resistance mean value (197.13 \pm 48.5 N) than **Celtra Duo** one (177.81 \pm 27.08 N) as tested by un-paired t-test ($p = 0.4591 > 0.05$) as shown in in table (2) and figure (2).

Comparison between both materials with 125° loading angle

It was found that **e.max group** recorded statistically non-significant higher fracture resistance mean value (188.29 \pm 17.89 N) than **Celtra Duo** one (166.16 \pm 23.43 N) as tested by un-paired t-test ($p = 0.1317 > 0.05$) as shown in in table (3) and figure (3).

TABLE (1) Fracture resistance test results (Mean \pm SD) as function of material groups and loading angle

Variables		Descriptive statistics			t-test	
		Mean \pm SD	95% confidence intervals		P value	
			Lower	Upper		
Material group	e.max	60° angle	197.13 ^A \pm 48.5	154.6	239.6	0.7121 ns
		125° angle	188.29 ^A \pm 17.89	172.6	204	
	Celtra Duo	60° angle	177.81 ^A \pm 27.08	154.1	201.5	0.4874 ns
		125° angle	166.16 ^A \pm 23.43	145.6	186.7	
ANOVA test		P value	0.4606 ns			

*Different superscript letter in the same column indicating statistically significant difference ($p < 0.05$) *; significant ($p < 0.05$) ns; non-significant ($p > 0.05$)*

TABLE (2) Comparison of fracture resistance test results (Mean ± SD) between both material groups with 60° loading angle

Variables	Descriptive statistics			
	Mean ± SD	95% confidence intervals		
		Lower	Upper	
60° fracture angle	e.max	197.13 ±48.5	154.6	239.6
	Celtra Duo	177.81 ±27.08	154.1	201.5
t- test	P value	0.4591 ns		

*; significant (p < 0.05) ns; non-significant (p>0.05)

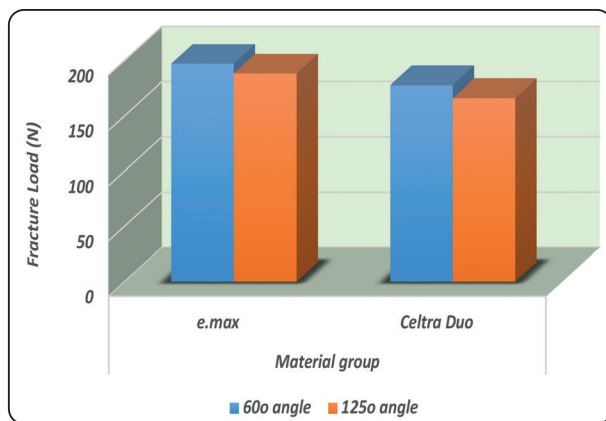


Fig. (1) Column chart showing the mean values of fracture resistance for both materials groups with different loading angle.

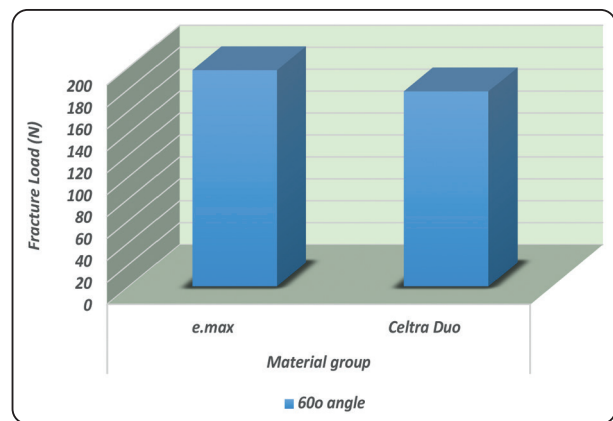


Fig. (2) Column chart comparing the mean values of fracture resistance for both groups with 60° loading angle.

TABLE (3) Comparison of fracture resistance test results (Mean ± SD) between both material groups with 125° loading angle

Variables	Descriptive statistics			
	Mean±SD	95% confidence intervals		
		Lower	Upper	
125° fracture angle	e.max	188.29 ^A ±17.89	172.6	204
	Celtra Duo	166.16 ^A ±23.43	145.6	186.7
t- test	P value	0.1317 ns		

*; significant (p < 0.05) ns; non-significant (p>0.05)

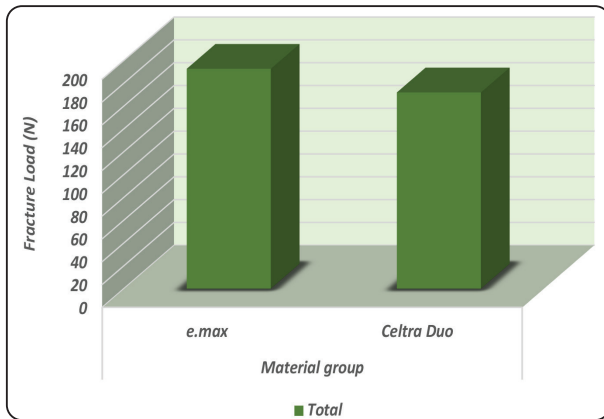


Fig. (3) Column chart comparing the mean values of fracture resistance for both groups with 125o loading angle.

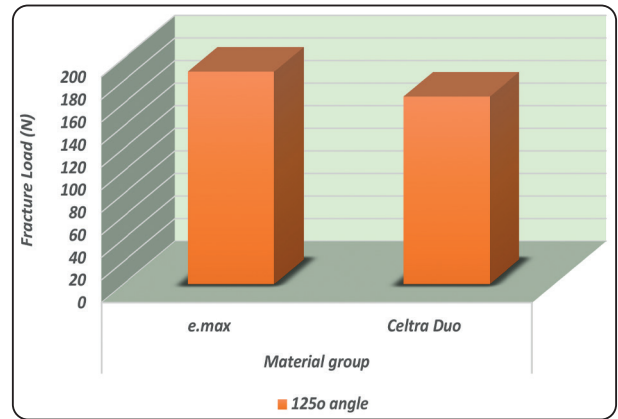


Fig. (4) Column chart comparing total fracture resistance mean values between both material groups

Total effect of material groups on fracture resistance

Irrespective of loading angle, totally it was found that that **e.max** group recorded higher fracture resistance mean value (192.71±33.19 N) than **Celtra Duo** one (171.98 ±25.25 N). The difference between material groups was statistically **non-significant** as designated by two- way ANOVA followed by Tukey’s pair-wise post-hoc test (F=1,1, P=0.3005 > 0.05) as shown in in table (4) and figure (4).

TABLE (4) Comparison of total fracture resistance test results (Mean±SD) as function of material groups

Variables	Mean	SD	Statistics		
			F value	P value	
Material group	e.max	192.71	33.19	1.1	0.3005ns
	Celtra Duo	171.98	25.25		

*; significant (p < 0.05) ns; non-significant (p>0.05)

Total effect of loading angle on fracture resistance mean value;

Regardless to material group, totally it was found that **60°** angle subgroup recorded statistically **non-significant** higher fracture resistance mean value (187.47) than **125°** one (177.22) as proved by two way ANOVA (F=0.3, P=0.6040 > 0.05) - table (5) and figure (5)

TABLE (5) Comparison of total fracture resistance results (Mean±SD) a function of loading angle

Variables	Mean	SD	Statistics		
			F value	P value	
Fracture angle	60°	187.47	37.97	0.3	0.6040 ns
	125°	177.22	20.66		

*Different letter in the same column indicating statistically significant difference (p < 0.05) *; significant (p < 0.05) ns; non-significant (p>0.05)*

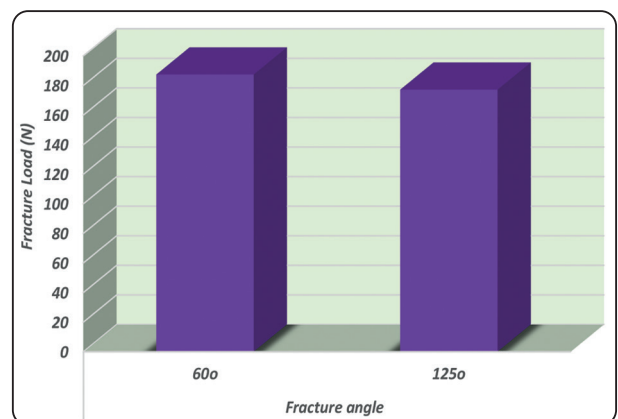


Fig. (5) Column chart comparing total fracture resistance mean values as function of loading angle.

DISCUSSION

Due to rising patient demand for aesthetics and conservative restoration, ceramic veneers have been a commonly utilised and effective procedure for treating discoloured, damaged, misshaped, or fractured teeth during the last decade.^(5,6) A zirconia reinforced lithium silicate for dental CAD/CAM applications has recently been released to the market for the fabrication of inlays, onlays, partial crowns, veneers, anterior and posterior crowns, and anterior and posterior single tooth restorations on implant abutments.⁽²⁾

This innovative glass ceramic has a zirconia content of 10% by weight. It's the first lithium silicate ceramic with zirconia reinforcement. This newly created generation of glass ceramic materials, according to the company, combines the good material features of zirconia (ZrO₂) and glass ceramics.⁽²⁾

The zirconia particles are used to support the ceramic structure by preventing cracks from growing. It has been hypothesised that the structure formed following crystallisation has improved mechanical features and meets the highest aesthetic standards. Because of the increased translucency and varied colours, it is anatomically shaped as a monolithic restoration.⁽²⁾ Four unique features must exist for a clinically effective dental restoration: marginal integrity, biocompatibility, aesthetics, and mechanical strength. The occlusal load is another important factor that affects the long-term efficacy of ceramic veneers. As a result, the direction in which load is applied during testing has a significant influence on the final result. Therefore, the goal of this study was to compare the fracture resistance of laminate veneers made of two ceramic materials: Zirconia reinforced lithium silicate glass-ceramic (Celta DUO) and Lithium disilicate glass ceramics (e-max CAD) under different load angulations (60°, 125°).

the current study focused on maxillary central incisors of approximately identical size. Because these are the most typically treated teeth with lami-

nate veneers, Artificial teeth, often known as bovine teeth, differ from human teeth in terms of flexibility, strength, and bonding characteristics.

To ensure perfect centralization of the teeth in the epoxy resin blocks, a centralizing device was used.

To standardize the preparation design, tooth preparations were carried out using a computer numerically controlled milling machine.

Silicon indexes were also used to check the depth and design of the final preparation. This approach maintained that the tooth structure was retained while the reduction was equal.

The butt joint design for laminate veneers was chosen because, when compared to other designs, it was found that this design decreases stress concentration in a ceramic veneer.⁽⁷⁾

Furthermore, the butt-joint design was proven to improve the bonding surface area and enable better occlusal load distribution.⁽⁸⁾ The butt-joint preparation was easier, less time-consuming, and more accurately duplicated on the master cast than tooth preparation with palatal chamfer, and there was no risk of fracture for thin supporting palatal ledges of ceramics. The butt joint was also useful in preventing palatal ceramic cracks caused by intraoral heat pressures.⁽⁹⁾

Restorations were machined utilizing a 4-axis CAD/CAM technology, which allows for the manufacture of the restoration in a reasonable amount of time while maintaining a high level of precision.⁽¹⁰⁾

The samples were standardized using the Cerec software 4.4 Biogeneric-copy mode, which allowed each restoration to be designed and machined as an identical duplication of the original anatomy.

In the present study, both e.max CAD and the newly introduced Celtra duo ceramics were chosen to be studied.

E. max CAD is a lithium disilicate ceramic with

a large number of microstructural, interlocking, needle-like lithium disilicate crystals contained in a glassy matrix, making it one of the strongest glass ceramics.⁽¹¹⁾

While **Celtra duo** is a zirconia-reinforced lithium disilicate ceramic with a fine-grained and homogeneous structure. It is a glass ceramic material reinforced with zirconium dioxide concentration approximately ten times that of typical CAD/CAM glass ceramic.

These ceramics have a flexural strength of 370-420 MPa after glazing, and an attractive appeal that is "as natural as a natural tooth" in appearance (natural opalescence, fluorescence, and strong chameleon effect).⁽¹²⁾⁽¹³⁾⁽¹⁴⁾⁽¹⁵⁾

Hydrofluoric acid was used to treat the fitting surfaces of laminate veneers, which alters the microstructure of the ceramic by damaging the glassy phase. This phase dissolves more readily, resulting in micro pores, which are necessary for bonding. Because the ceramic contains silane-bondable components like silica, the bonding process can be aided by using a silane coupling agent.

Phosphoric acid (37%) was used to treat the prepared tooth structure, which is necessary to improve the bonding process.⁽¹⁶⁾

Resin cements exhibit a diverse bonding potential with glass ceramics. A study performed by **Pagniano et al in 2005**⁽¹⁷⁾ concluded that Glass ceramic fracture resistance has been found to improve with resin cementation utilizing a comparatively thin layer⁽¹⁷⁾. Light-cured resins are often preferred to chemically cured or dual-cured resins because of their color stability easier removal of any excess material before light-curing thus reduces the finishing time required after cementation of the restorations⁽¹⁸⁾ and 'polymerization on demand' characteristics.⁽¹⁹⁾

Thus, light cured resin cement was used for cementation of veneers.

Thermal cycling is an in-vitro process often represented in these simulations. There are too many variance of cycles number used from 1 to 1 000 000 cycles.⁽²⁰⁾

In the present study, all samples were subjected to 2000 cycles, which were equivalent to one year in service⁽²⁰⁾

Mechanical testing was carried out on all of the specimens using the universal testing machine. Because the direction of applied force during functional activities such as chewing and swallowing has a significant effect on veneer survival, this study employed two loading angles (60° and 125°) to simulate load applied during tearing/intercuspal and protrusive positions.⁽¹⁾

A designed plunger was used to transmit load to the incisal edge of each specimen at a crosshead speed of 1.0 mm/min. In Newtons, the maximum force necessary to break each specimen was calculated.

The e.max group had a statistically **non-significant** greater fracture resistance mean value than **the Celtra Duo** group in our study. The null hypothesis was **accepted** based on our findings.

Although **non-significant**, e.max laminate veneers showed a higher fracture resistance value than celtra duo. This was in accordance with **Preis et al**, who examined the fracture resistance of lithium disilicate and zirconia reinforced lithium disilicate crowns and they found that e-max CAD higher fracture resistance values than celtra duo. The high fracture resistance values of e-max CAD were reasonable due to the development of the high crystalline content of fine highly-interlocking lithium disilicate crystals embedded in the glassy matrix after crystallization.. Additionally, **Guazatto et al**, attributed the increase in the flexural strength of e-max CAD to the introduction of tangential compressive stresses within the material resulting in crack deflection and subsequent resistance to crack propagation. **Sagsoz**

et al and Apel et al stated that the same explanation in their previous studies.⁽²¹⁾

On the other hand, the newly tested Celtra Duo material gives comparable results to e-max CAD material. The incorporation of 10% zirconia which is completely dissolved in the glass phase proposing homogenous ultrafine crystalline microstructure provides this material with high strength. It was expected that addition of zirconia to lithium disilicate ceramics will improve their fracture resistance, however, they give almost the same results.

Furthermore, our findings revealed that in both groups (e-max CAD & Celtra Duo laminate veneers) 60° loading angle recorded higher Fracture resistance than 125° loading angle.

Gibbs et al. disagreed with the findings of our current study, saying that intercuspal position is crucial for functional activities like chewing and swallowing. The forces produced are largest and strongest in this position, whereas the forces created during eccentric contacts during functional movements are very low.

Clinically, intercuspal forces are strong, and thus specimens fractured at low fracture load value at this angle. At 125° angle, which simulated eccentric position, i.e., protrusive position, more fracture load value was required to fracture the specimen owing to the low-force value generated clinically at this position. It has been observed that the maximum masticatory forces for maxillary anterior teeth are 130N. The load to failure in the current study was high enough in all groups to exceed the tooth's proportional limit.

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