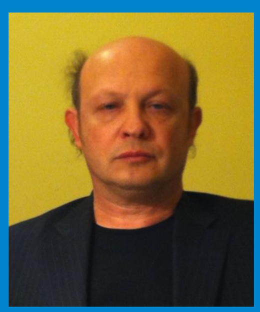
Fatigue resistance of monolithic and layered zirconia and $LiSi_2$ crowns.



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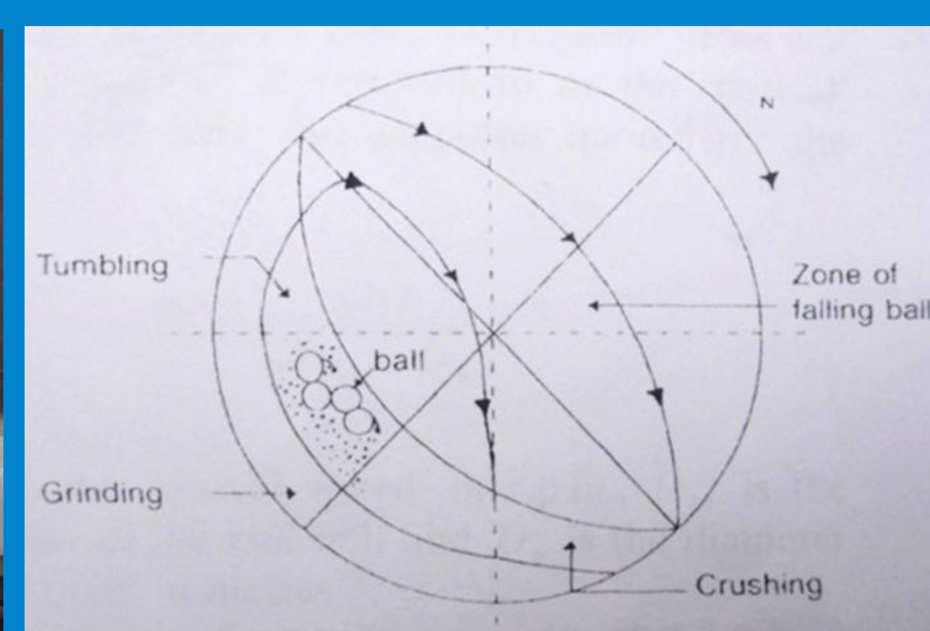
OBJECTIVE: Zirconia and lithium disilicate ceramic materials can be milled to obtain both layered and monolithic crowns. Monolithic all-ceramic crowns are reported to be more resistant than layered counterparts and cost-effective. However, many studies just evaluate the ultimate fracture resistance of the restorations by static loading, a condition which seldom occurs in the oral environment. Fatigue stresses are more closely related to the damage accumulation that leads to the restoration failures observed in the clinical practice. The aim of this study was to evaluate the fatigue resistance of zirconia and lithium disilicate monolithic crowns comparing the surviaval rate with their layered counterparts.

MATERIALS AND METHODS: An upper incisor and a canine were prepared to receive all-ceramic restoration. For each tooth, 6 monolithic and 6 layered crowns were replicated using CAD/CAM technology. The ceramics used to make the monolithic crowns were IPS e.max CAD lithium disilicate (Ivoclar-Vivadent) and Lava Plus zirconia (3M-ESPE); layered crowns were made by veneering the ceramic copings of the same above-mentioned ceramics with pressed-on IPS e.max Ceram (lithium disilicate) and IPS e.max ZirPress (zirconia). The crowns were cemented on epoxy resin composite abutment replicas using a luting cement (BisCem, Bisco). The fatigue machine used in this study is a sealed rotating stainless steel drum which contains alumina and zirconia spheres along with the specimen population to be tested. During rotation at 172.5 rpm in 37°C saline solution, the balls generate wear and random impact stresses of a known maximum theoric energy (0.316 J) able to induce cracks growth and fracture propagation in brittle materials. The ball-mill was opened after 10 minutes then every 30 minutes for specimens weighing (total testing time 340 minutes). Failures pattern were evaluated under a stereomicroscope using transillumination. Kaplan-Meier survival curves and multiple comparison tests have been performed (α=0.05).



The Ball Mill fatigue machine: the drawing shows the kinetic of the spheres (zirconia ceramic) which generate damage accumulation on the ceramic restoration. from: Abu Kasim NH. The ball mill as a means of investigating the mechanical failure of dental materials. J Dent. 1996 Jan-Mar;24(1-2):117-24.

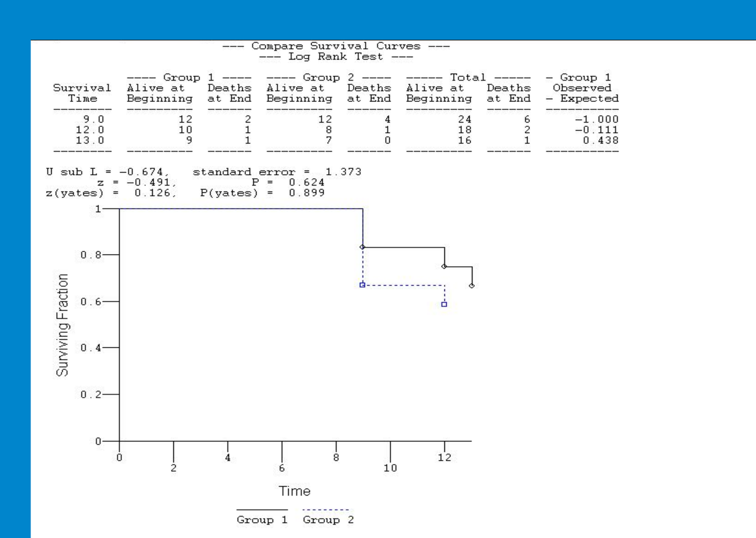
Example of the highly standardized LiSi2 monolithic and layered crown population tested in this study

RESULTS: Monolithic zirconia crowns demonstrated the highest survival rate among the four groups tested, with not detectable ceramic fractures or losses, whereas layered zirconia crowns the lowest ($p<0.001$). The layered crowns failed progressively by veneering ceramic chipping (material loss 1.4 to 19.4% of the initial weight); the loss was significantly greater in incisor teeth rather than in canines ($p<0.05$). No significant differences were found among monolithic and layered lithium disilicate crowns ($p=0.624$): they were found to be significantly more resistant than zirconia layered crowns and significantly less resistant than monolithic zirconia ($p<0.05$). Both cohesive and adhesive failures of the veneering ceramic with the ceramic core were observed, as well as lithium disilicate ceramic, whereas no fractures of the zirconia ceramic occurred.

The tables below illustrate the weight losses (grams) and catastrophic failures (red numbers) in the 48 ceramic crown population. Only survival comparison (graphs) between monolithic and layered crowns within each material (ZrO2 or LiSi2) is shown.

Group A	Total weight	T1 10'	T2 20'	T3 50'	T4 80'	T5 110'	T6 140'	T7 170'	T8 200'	T9 230'	T10 260	T11 290'	T12 310'	T13 340'	T14 370'
INCISOR LiSi2 Monolithic															
A1	0.47	0.47	0.47	0.47	0.47	0.47	0.46	0.46	0.46	0.45					
A2	0.51	0.51	0.51	0.51	0.51	0.51	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
A3	0.48	0.48	0.48	0.48	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47
A4	0.48	0.48	0.48	0.48	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45	
A5	0.46	0.46	0.46	0.46	0.45	0.45	0.47	0.45	0.45	0.45	0.45	0.45	0.45	0.45	0.45
A6	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.47	0.45	0.43					
CANINE LiSi2 Monolithic															
A7	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
A8	0.71	0.71	0.71	0.71	0.71	0.70	0.70	0.70	0.69	0.69	0.69	0.69	0.69	0.69	0.69
A9	0.73	0.73	0.73	0.73	0.73	0.73	0.72	0.72	0.71	0.70	0.70	0.70	0.69	0.69	0.69
A10	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.72	0.72	0.72	0.71	0.69	0.69	0.69	0.69
A11	0.72	0.72	0.72	0.72	0.73	0.73	0.71	0.71	0.71	0.71	0.71	0.70	0.70	0.70	0.70
A12	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.71	0.70	0.70	0.69	0.69	0.69	0.69	0.69

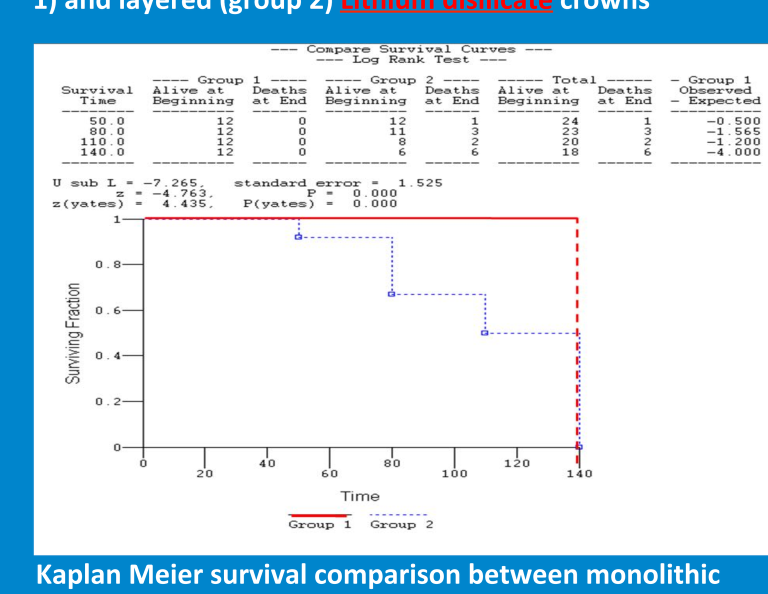
Group B	Total weight	T1 10'	T2 20'	T3 50'	T4 80'	T5 110'	T6 140'	T7 170'	T8 200'	T9 230'	T10 260'	T11 290	T12 310'	T13 340'	T14 370'
INCISOR LiSi2 Layered															
B1	0.47	0.47	0.47	0.47	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.44	0.44		
B2	0.46	0.46	0.46	0.46	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.44
B3	0.47	0.47	0.47	0.47	0.45	0.45	0.45	0.45	0.45	0.43					
B4	0.47	0.47	0.47	0.47	0.47	0.46	0.46	0.30	0.30	0,25					
B5	0.47	0.47	0.47	0.47	0.44	0.44	0.44	0.44	0.42	0.40					
B6	0.45	0.45	0.45	0.45	0.45	0.45	0.40	0.40	0.40	0.38					
CANINE LiSi2 Layered															
B7	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.67	0.67	0.67	0.67	0.67	0.67	0.67
B8	0.69	0.69	0.69	0.69	0.69	0.68	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
B9	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.68	0.68
B10	0.70	0.70	0.70	0.70	0.70	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
B11	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.68	0.68	0.68	0.68	0.68	0.68	0.68	0.68
B12	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71



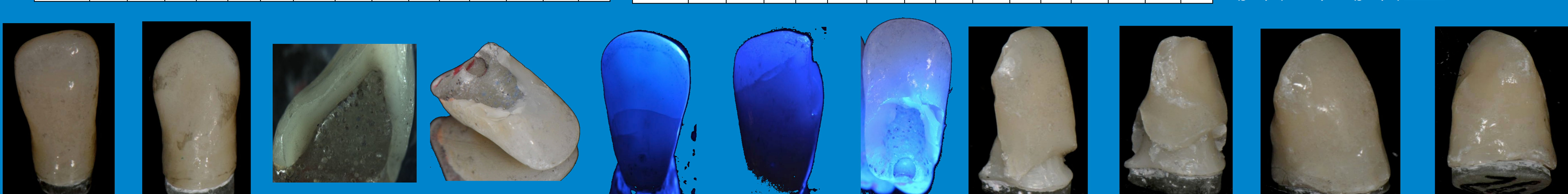
Kaplan Meier survival comparison between monolithic (group 1) and layered (group 2) Lithium disilicate crowns

Group C	Total weight	T1 10'	T2 20'	T3 50'	T4 80'	T5 110'	T6 140'	T7 170'	T8 200'	T9 230'	T10 260	T11 290'	T12 310'	T13 340'	T14 370'
INCISOR ZrO2 Monolithic															
C1	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
C2	1.41	1.41	1.41	1.41	1.41	1.41	1.41	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
C3	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
C4	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37	1.37
C5	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.38	1.38	1.38	1.38	1.38	1.38	1.38	1.38
C6	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
CANINE ZrO2 Monolithic															
C7	1.82	1.82	1.82	1.82	1.82	1.82	1.82	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81
C8	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.79
C9	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.77
C10	1.83	1.83	1.83	1.83	1.83	1.83	1.83	1.81	1.81	1.81	1.81	1.81	1.81	1.81	1.81
C11	1.79	1.79	1.79	1.79	1.79	1.79	1.79	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.78
C12	1.78	1.78	1.78	1.78	1.78	1.78	1.78	1.77	1.77	1.77	1.77	1.77	1.77	1.77	1.77

Group D	Total weight	T1 10'	T2 20'	T3 50'	T4 80'	T5 110'	T6 140'	T7 170'	T8 200'	T9 230'	T10 260	T11 290'	T12 310'	T13 340'	T14 370'
INCISOR ZrO2 Layered															
D1	0.98	0.98	0.98	0.94											
D2	0.95	0.95	0.95	0.95	0.95	0.83									
D3	0.97	0.97	0.97	0.97	0.97	0.83									
D4	0.95	0.95	0.95	0.95	0.87										
D5	0.96	0.96	0.96	0.96	0.96	0.96	0.87								
D6	0.94	0.94	0.94	0.94	0.86										
CANINE															
D7	1.39	1.39	1.39	1.39	1.39	1.39	1.36								
D8	1.39	1.39	1.39	1.39	1.39	1.39	1.35								
D9	1.43	1.43	1.43	1.43	1.43	1.43	1.40								
D10	1.44	1.44	1.44	1.44	1.44	1.44	1.42								
D11	1.45	1.45	1.45	1.45	1.41										
D12	1.40	1.40	1.40	1.40	1.40	1.40	1.37								



Kaplan Meier survival comparison between monolithic (group 1) and layered (group 2) zirconia crowns



Failures ranged from subclinical cracks revealed by transillumination to massive chipping and coping fracture. Only monolithic zirconia crowns (left) ended the fatigue cycling with no catastrophic damages

CONCLUSION: monolithic zirconia crowns are notably more resistant than layered ones, whereas no differences were found between monolithic and layered lithium disilicate crowns. Layered zirconia crowns showed early chipping and were the less resistant among the crowns tested, they should be avoided as restorations on strongly stressed teeth.

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