Wear in composites: An *in vitro* study on dental composite fillers

V. Kalliyana Krishnan*,† and Lawrence H. Mair§

§Department of Clinical Engineering, University of Liverpool, Liverpool L69 3BX, UK
*Present address: BMT Wing, Sree Chitra Tirunal Institute for Medical Sciences and Technology, Thiruvananthapuram 695 012, India

Two-body and three-body wear of four light-cured dental composites have been studied *in vitro* and their results compared. Two-body wear is found to be higher for Profile TLC and P-30 containing filler particles of conventional size (< 50 μm), whereas microfilled Heliomolar tends to show a high rate of wear during three-body abrasion. Chitra composite containing hybrid filler particles is found to possess wear characteristics comparable to imported controls.

THE phenomenon of wear is one of the most important parameters affecting the clinical performance of dental composites[1–3]. However, there is a tremendous amount of confusion in the dental literature concerning the processes of wear. It is often considered as a single process although it involves several mechanisms, all of which may be active in the mouth[4]. For a simple understanding, wear can be divided into two-body and three-body wear. In the mouth, two-body wear results from direct contact between the teeth while with three-body wear, there is an intervening abrasive slurry. The latter is formed mainly by abrasive particles in the masticatory slurry. The main difference in manifestation is that two-body wear is confined to sites of direct contact between the surfaces whereas slurry wear occurs across the entire surface[5]. On restorations, two-body wear may appear as isolated wear scars whereas three-body wear causes the restoration surface to 'submerge' into the cavity, leaving enamel exposed at the margin[6].

As the two processes have different causal factors, it is important that they are studied separately[7]. Here we study the two types of wear in three commercially available composites and one which has been developed in India. Although *in vitro* studies need not necessarily predict clinical performance, they are useful to determine the effect of mechanisms which will be encountered in the mouth[4].

Four light-curing dental composites were used in the study (Table 1). It is important to note that the material Heliomolar is a microfilled composite composed of colloidal silica fillers (dia ~ 0.04 μm) incorporated as pre-polymerized particles[8]. The Chitra material is a hybrid material having a small portion of colloidal silica dispersed between larger quartz fillers. Samples of the composites were fabricated by packing the material into molds and photoinitiating in 2 mm increments to ensure adequate conversion.

The two-body wear of the four composites was studied using a twelve station reciprocating sliding pin wear machine developed at the University of Liverpool. At each wear station, the composite specimen was moved 7 mm in one direction rubbing against a ceramic ball counterface. This was attached to a hinged arm carrying weights which applied the load onto the specimen (through the ceramic ball). After sliding in one direction, the arm was lifted so that no load was applied as the specimen moved back to the cycle start position. The light-cured composite samples were 10 mm in length × 5 mm width × 2.5 mm depth. At least six specimens of each material were exposed to 500,000 cycles taking measurements at regular intervals. The total load on the counterface was 200 g.

Three-body wear was studied using a slurry wear tester. The abrasive was alumina (1 μm) suspended in water and dispersed on a felt platen. This rotated in contact with six wear stations which had the composite specimens glued onto weighed rods. At regular intervals, the rods were removed and the loss of height of the specimens measured with a comparator. The cylindrical specimens were 7 mm dia × 1.5 mm height and a minimum of six samples of each material was tested. Prior to testing, the resin-rich layer was removed from the wear surface with silica carbide abrasive paper. Measurements were made at 1 min intervals up to 10 min and then at 5 min intervals to 30 min. The load on each rod was 150 g.

Statistical calculations were carried out using both two-body and three-body wear values obtained after 500,000 cycles and 30 min of operation respectively using Student's *t* test (Table 2).

Figures 1 and 2 show the two-body and three-body wear respectively for the dental composites. The initial rapid wear for the two-body wear can be explained because the resin-rich layer had not been removed prior to testing. This layer wears very rapidly because of its low filler content. There was steady state wear in the three-body study because the resin-rich layer was removed prior to testing. The minor fluctuations in the two-body wear curves were caused by daily variations in the transducer readings which were sensitive to the ambient temperature (higher readings were noted when the room temperature was high).

For two-body wear, Profile TLC and P-30 had a greater rate of increase than Heliomolar and Chitra. The low value for Heliomolar can be explained because, as a microfilled material, it maintains a low coefficient of friction which reduces this type of wear[4]. The low wear of the Chitra material may result from its relatively hard quartz filler particles compared to the softer glass fillers in P-30 and Profile TLC. At one time, it was

†For correspondence. (e-mail: bmtwing@md2.vsnl.net.in)

Table 1. Composite materials used

Material	Manufacturer	Monomers	%	Fillers	Mean size (μm)
Chitra	SCTIMST, Thiruvananthapuram, India	BIS-GMA TEGDMA	65–75 35–25	Quartz Colloidal silica	> 20 ~ 0.04[a]
Heliomolar	VIVADENT, Schann, Liechtenstein	BIS-GMA EDMA	69 22	Colloidal silica	0.04 (10)[b]
P-30	3M Co., MN, USA	BIS-GMA TEGDMA	54 46	Zinc glass	3.0
Profile TLC	SS WHITE, Pa, USA	BIS-GMA EGDMA	64 34	Strontium glass	8.0

BIS–GMA, Bisphenol A-glycidyl methacrylate.
EGDMA, Ethylene glycol dimethacrylate.
TEGDMA, Triethylene glycol dimethacrylate.
[a]Dispersion of colloidal silica in hybrid material.
[b]Mean size of pre-polymerized particles.

Table 2. Mean and standard deviation values for two- and three-body wear of four composites under study after 500,000 cycles and 30 min respectively (in μm)*

Material	Two-body wear after 500,000 cycles	Three-body wear at 30 min
Chitra	32.67 ± 8.83	35.60 ± 12.03
Heliomolar	48.33 ± 21.96	487.60 ± 106.34
P-30	75.67 ± 36.90	50.40 ± 12.22
Profile TLC	75.33 ± 25.45	71.60 ± 9.67

*Difference in wear values joined by same vertical line are not statistically significant.

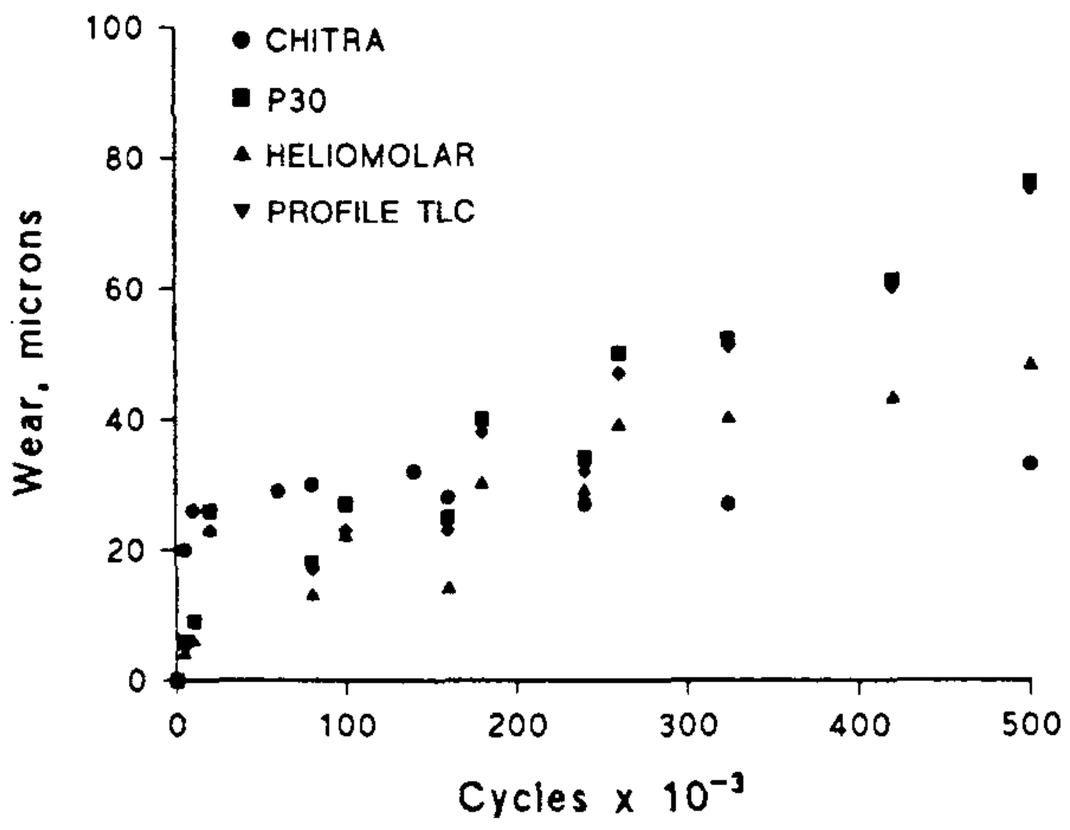

Figure 1. Two-body wear pattern of light curing composites plotted against number of wear cycles.

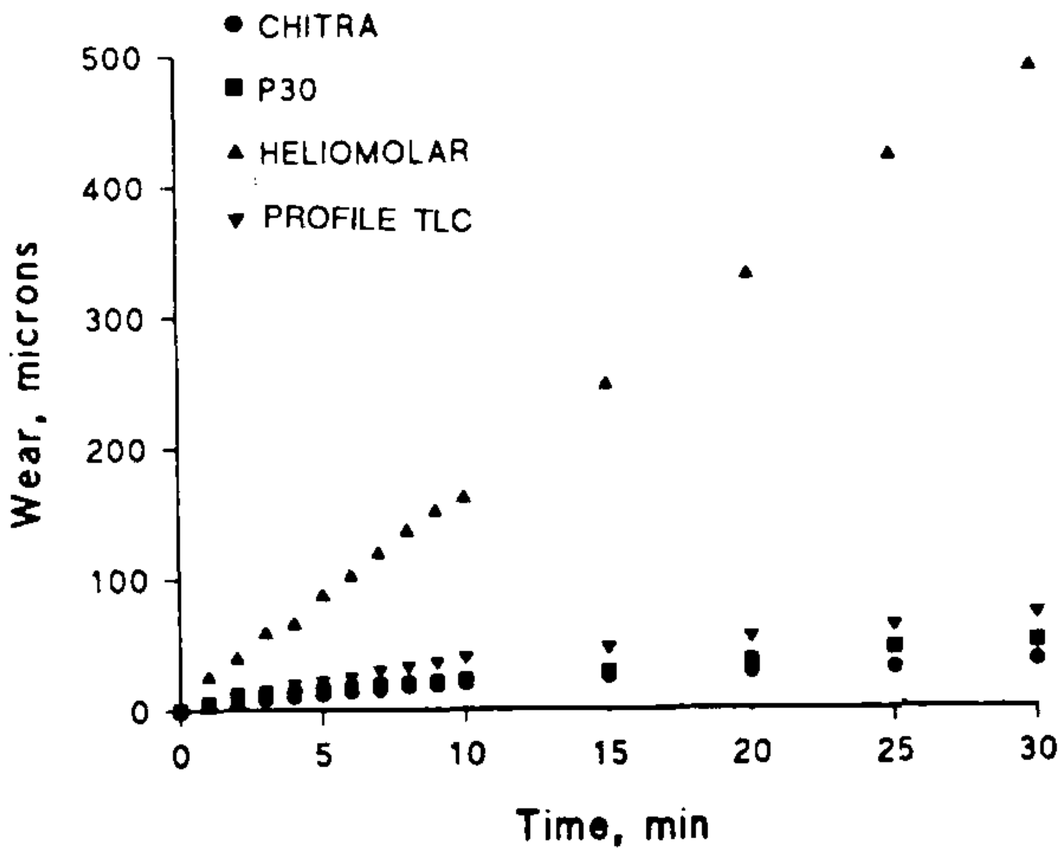

Figure 2. Three-body wear pattern of light curing composites plotted against wear time in min.

postulated that the use of softer glass would improve wear resistance by allowing fracture instead of displacement of fillers. The materials P-30 and Profile TLC were developed in accordance with this theory. However, in a clinical trial of three posterior composites, quartz-filled materials had the best wear resistance[2,7]. Our *in vitro* result for the Chitra material corresponds to this finding. The small amount of colloidal silica in this hybrid material may also decrease the friction by maintaining a relatively smooth surface.

As far as three-body wear is concerned, it is apparent from Figure 2 that the microfilled material had a greatly increased wear rate over the other three materials (~ 500 μm after 30 min). This has been noted in previous studies of three-body wear with a microfilled composite[9]. It is caused because the small abrasive particles of the slurry are able to cut through the polymer matrix displacing the tiny fillers. The huge difference between the two-body and three-body wear results for this material shows the importance of studying each wear mechanism separately. The difference in the three-body wear between

the other materials was small although the Chitra material had the lowest wear rate. This may be because the colloidal silica particles occupy the space between the larger fillers giving enhanced protection to the polymer matrix.

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Petrochemistry and petrogenesis of Kalpatta granite, South India

S. N. Kumar*[,§], V. Prasannakumar[†] and P. K. R. Nair[†]

*Department of Geology, University College, Thiruvananthapuram 695 034, India
[†]Department of Geology, University of Kerala, Thiruvananthapuram 695 581, India

Kalpatta granite is one among the acid plutons puncturing the Precambrian rocks of Kerala consisting of three dominant phases. The polyphase pluton is a well-differentiated, calc-alkaline, peraluminous, post-orogenic, A-type granite ranging in composition from granite to granodiorite-adamellite. Geochemical discriminant diagrams, mineralogy, and major and trace element chemistry suggest that the variants are products of polyphase late magmatic crystallization.

PRECAMBRIAN rocks of Kerala are intruded by a variety of plutons, ranging in composition from ultrabasic to acidic. Acid igneous activity is manifested by granite intrusives falling within the span of 740 ± 30 Ma and 512 ± 20 Ma (ref. 1). Kalpatta granite, one among such plutons, has given a U–Pb zircon age of 765 Ma (ref. 2) and K–Ar age of 512 ± 14 Ma (ref. 3).

Kalpatta granite, an elliptical stock (area ca. 50 km^2), trending NNW–SSE, intrudes into the Precambrian crystallines, consisting of hornblende–biotite gneiss and charnockite. Pyroxene granulite, amphibolite and talc–tremolite–actinolite schist are seen as enclaves and bands in the gneiss (Figure 1). The rocks, except granite, have suffered high-grade metamorphism and polyphase deformation resulting in the formation of three generations of folds and a penetrative foliation. The granite pluton, discordant with the host rocks, contains enclaves of gneiss and charnockite near the contact. The overall characters of the pluton suggest that it is post-tectonic.

The granite pluton is massive except for a weak planar fabric near the contact. Surmicaceous[4], amphibolite and charnockite enclaves of different shapes and sizes are observed along the contact. The absence of enclaves of metasediments within the granite and absence of migmatite zone at the country rock-granite contact preclude the formation of the granite through partial fusion of metasedimentary country rocks. Though the granite appears to be homogeneous, textural and mineralogical variants, ranging from porphyritic to equigranular and

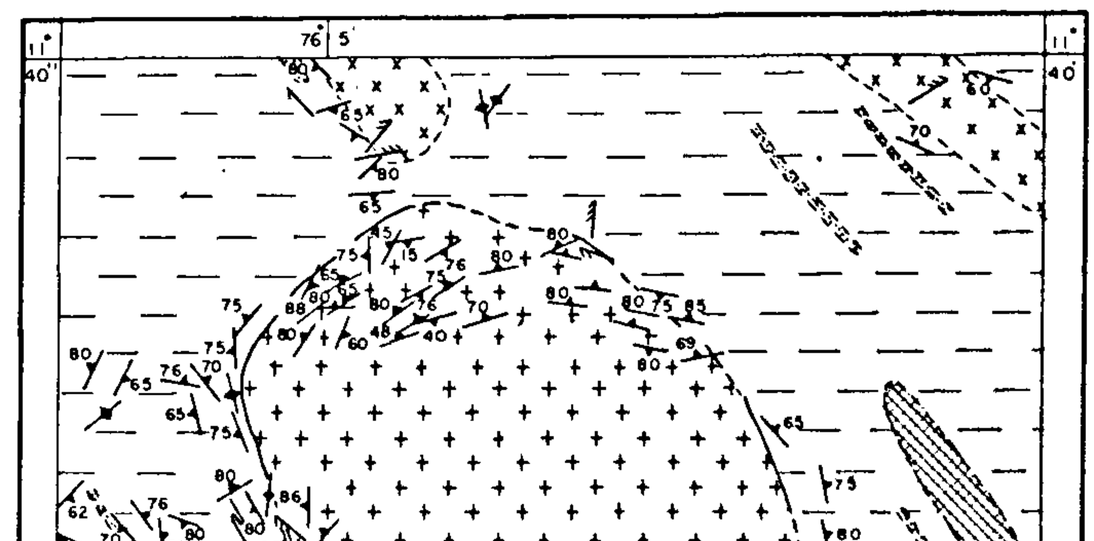

Figure 1. Geological map of the area around Kalpatta

§For correspondence.