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Mechanical Properties of Polymethyl Methacrylate-Ketoprofen Mixture in Stent and Splint Preparation

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ABSTRACT. Contribution of engineering to other fields is authentic and increasingly growing. The field of dentistry is an example of fields that are in need for wide and deep cooperation with engineering disciplines. The current work is aimed to investigate the possible change in mechanical properties and surface roughness of a widely used material in dentistry applications, Acrylic resin (Polymethyl methacrylate) after mixing it with Ketoprofen (2% to 10%). This mixing is sought to diminish the possible irritation that could be developed by patients sensitive to Acrylic resin (PMMA) usage. The effect of soaking the material in different solutions having variety of pH values was taken into consideration to simulate the actual service environment. Compressive, bending, and Izod impact tests were carried at room temperature for specimens of PMMA containing different fractions of Ketoprofen (0%, 2%, 5%, and 10%). Surface roughness were measured (Ra) along a period of 5000 hours of soaking in several solutions with different pH values (2, 5, 7, and 11). Only bending strength, among mechanical, was slightly increased with the increased fraction addition of Ketoprofen. Surface roughness was slightly affected with the addition of Ketoprofen. Soaking specimens in different solutions with varying pH showed some tendency to become slightly rougher as the solution has stronger pH value. This effect was more obvious in specimens containing 2% Ketoprofen.

KEYWORDS: Acrylic resin, Ketoprofen, Polymethyl Methacrylate, PMMA, mechanical properties, surface roughness, soaking.

1. Introduction

Acrylic resin is an indispensable material that has been used extensively for the fabrication of denture bases because of its esthetic quality, ease of manipulation and reparability. In spite of the undoubted qualities and excellent properties of standard heat-cure PMMA (Polymethyl methacrylate) as denture base there is occasionally a need for different polymers. The use of acrylic resin (hot and cold polymerizing) has become increasingly popular among neurosurgeons because of its tissue compatibility and the easiness of manipulation in surgery. Also it has the properties of poor thermal and electrical conductivity. Acrylic resin also used in construction of specialized splints and stents in the field of oral and maxillofacial surgery. Among these splints and stents is antihemorragic one, which some surgeons like to construct it to accurately hold homeostatic agents in place and prevent further damage to the extracted site. The use of such stents is not considered essential in the management of these patients by many other oral surgeons, as it is believed that it may act as a source of irritation and possible infection. So in this study, a trial to incorporate different ratios (2-10%) of well proved anti-inflammatory agent (Ketoprofen) in the Acrylic resin to decrease postoperative irritation or inflammatory reaction is being investigated. Ketoprofen, a nonsteroidal anti-inflammatory drug (NSAID), derived from 2-arylpropionic acid possesses a single chiral center creating two enantiomers with differential actions. Compared to other NSAIDs Ketoprofen exhibits marked potency in reducing prostaglandin synthesis in vitro and carrageenin-induced edema in vivo [1-4]. Other unique anti-inflammatory effects of Ketoprofen include its anti-bradykini activity, stabilization of lysosomal membranes, reputed inhibition of leukotriene release from activated cells and suppression of leukocyte migration [5-9], as treatment stents in patients having abused tissues.

Oral Ketoprofen has been used in the treatment of chronic rheumatoid arthritis, and osteoarthritis with a low incidence of renal, hepatic, or toxic reactions. Several studies have been performed on human subjects that suggest that Ketoprofen can be tolerated in dosages up to 300mg *per* day (usually taken 3 or 4 times *per* day). However there is interest in the use of Ketoprofen for the treatment of periodontitis. Ketoprofen is readily absorbed through the cutis, a property observed for other NSAIDs studied by Li *et al* [10], and Shah *et al* [11]. Based on this consideration, there is the potential for topical formulations of Ketoprofen to be absorbed through the oral mucosa, reducing inflammation of the gingival and periodontal tissues. Furthermore, a previous study investigated the application of Ketoprofen gal to maxillary dentures in 37 edentulous subjects and found no physical evidence of oral irritation, no changes in blood chemistry or complete blood count, and urinalysis results to be within the normal range of biological variability [12].

Accordingly, the pharmacokinetic analysis indicates systemic absorption of Ketoprofen when administered as topical intra-oral gels in different dosages under the described conditions. However, the relative bioavailability to the gels were lower than that of the oral capsule. There was no apparent accumulation of the drug in the plasma upon chronic administration. Current trends in pharmacokinetics favor the use of topical over systemic therapy, since topical therapy has the potential to deliver more drugs to the target tissue with less systemic absorption. Therefore, topical Ketoprofen gel should be considered as a safe alternative dosage form to Ketoprofen, given its lower systemic absorption and comparable safety profile [13].

There is no previous study for mechanical characteristics of the Acrylic resin when mixed with Ketoprofen to the knowledge of the author. However, many other previous publications reported mechanical properties of Acrylic resin and possibilities of enhancing them by adding other materials [14-20]. Anthony *et al* [21] included in their paper a survey of many materials that are used for dental purposes and showed comparisons for their compressive and bending strengths. Another study performed by Abu-Bakr, *et al* [22] included the effect of fluids with different pH values on both mechanical and surface texture of several dentally used materials. The present study helps in answering the questions regarding the usage of the modified Acrylic resin with Ketoprofen as a denture base without a loss in its mechanical properties. The study is also intended to answer the question of any possible degradation to surface smoothness of the modified Acrylic resin as a result of being soaked in solutions with different pH values.

2. Experimental Work

Conventional heat cured acrylic resin (1) samples cured by water bath at 73°C± 1°C were prepared for this study. Ketoprofen was added in the following ratios (0,2,5,10 % W/W).

Preparation of Samples

1. Ketoprofen powder as previously mentioned ratios was added to the polymer powder, which was mixed by electrical checker (2) to obtain homogenous mixture.
2. The specimens of this study were prepared following three layers conventional flasking technique, using plaster of Paris (3) as an investing medium.
3. Two aluminum bars were used in each brass flask for preparing the mold cavity.

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(1) Acrostone Denture base material manufactured by Acrostone Dental Factory under Exclusive License VIV England.
(2) Instruments Inc. Melrose Park.Ill.
(3) Plaster of Paris, Sina Gyps Company, Gypssina Egypt.

4. Packing of the modified resin was kept at 1000 K Pa using hydraulic bench press [(1)] .
5. Curing was performed using digitalized water bath unit at 73°C± 1°C. After curing, the specimens were carefully removed from the flask and carefully finished with sand paper 220, 320 and 400 Grit.

Three Point Bending

Flat shaped specimens of 100-mm length were used for transverse bending testing. The specimens were prepared according to ADA No. 12 standard. A 200 KN loading capacity (Testometric) [(2)] universal testing machine was used to perform three point. Additional loading due to geometry was avoided since symmetric bending is achieved. Cross head speed was maintained constant during all tests and kept at 5 mm/min. Peak loads were recorded for each individual test and used to calculate bending stress, σ, according to the following equation.

$$\sigma = \frac{ply}{4I} \quad MPa$$

where

p = peak load in MN.
l = specimen length between points of support in meters.
y = distance from the center of the cross –section to upper surface in meters.
I = Second moment of area of the trapezoidal cross section area of specimen (m^4)

Compressive Strength

Square shaped specimens of a twice as much length to lateral dimension were used to determine compressive strength. The same universal testing machine which was used to perform transverse bending tests, was used for compressive tests. Crosshead speed was also restricted at 5 mm/min.

Impact Tests

Impact Tests were conducted at room temperature in order to show the behavior of the materials being investigated under impact at room temperature. Slightly trapezoidal shaped specimens of 100-mm length were prepared

(1) Reco, Olhydraumatic-Pressen hydraumatic HMP Germany.
(2) Testometric 200 K N. Vitfk International Ltd., Manchester- England.

according to No. 771 of British Standard Inst. The trapezoidal shape of specimens was determined for the ease of pulling of specimens out of the mold during the preparation phase. Specimens were prepared with machined notches. Izod Impact device (1) was used to perform impact tests for the material being investigated. Five specimens were tested for each case (inclusion percentage of Ketoprofen) and the average results were determined.

Surface Roughness

Specimens measuring 10x20x2 mm were soaked into distilled water at different pH values (2, 5, 7, 11) for a period of time that ranged from 0- up to about 4800 hours (200 days) to detect the soaking time effect on the surface of the specimens with different percentages of Ketoprofen. The surface roughness was tested by Mitutoyo-Surftest SV-402/414. Measurements were taken each time at 3 different locations on each specimen then results were averaged.

3. Results

Figure 1 summarizes the testing results of compressive strength for Acrylic resin specimens with different inclusion percentages of Ketoprofen powder (0%, 2%, 5%, and 10%). All tests carried out at room temperature with same testing conditions. Each point in Fig. 1 represents the average results of 4 specimens. The standard deviations ranged form 0.00138 to 0.187021. Almost no change in compressive strength was displayed by the results especially by specimens containing 10% of Ketoprofen except a very slight decrease was noticed for specimens containing 10% Ketoprofen.

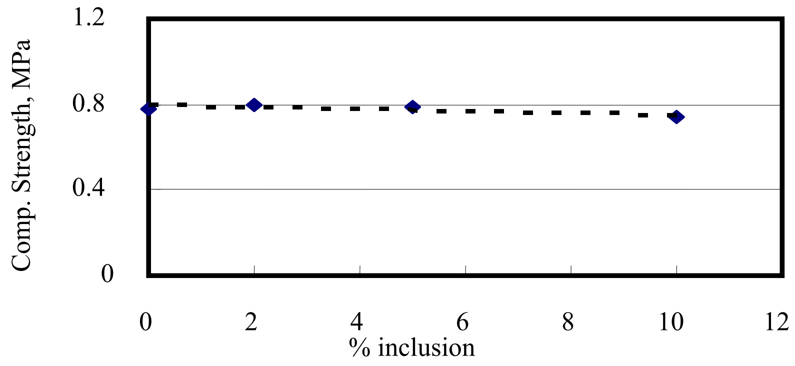

Fig. 1. The results of averaged compressive strength.

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(1) Impact device Brooks Model IT 14, Brooks Inspection Equipment LTD, 134 LEXDEN Road Cholchester, ESSEX.CO34BL, England.

Average bending strength results at different additive percentages are shown in Fig. 2. A slight change has occurred in bending strength as a result of adding Ketoprofen. A slight increase in bending resistance was displayed by specimens containing increased percentages of Ketoprofen. This may suggest that tensile properties may have been slightly improved by the increase of the additive material. This contributed to a general improvement in mechanical response of the material. On the other hand, Fig. 3 outlines the averaged impact energy for four groups of specimens with the indicated inclusion percentage. The standard deviation of first group (0% inclusions) was 0.5453, and for the three groups with 2%, 5% and 10% Ketoprofen inclusions were 0.2593, 0.1662, and 0.1186 respectively. There was no obvious change in Izod impact energy due to the change of Ketoprofen percentage added to the matrix material. Figures 4a through 4d show the effect of the soaking time on the surface roughness of the specimens with different additive percentages. The parameter R_a was considered as a measure for surface roughness. The parameter Ra was measured on a “Telsurf” instrument expressed in µm. Tests were carried out along span time of about 5000 hours. Readings of roughness parameters were taken on intervals of 2 to 5 days in laboratory conditions. As a general trend, the increased Ketoprofen additive percentage contributed to a little degradation in the surface roughness (increase of R_a) of the specimens specially when soaked in higher pH solutions. This was most obvious in specimens with additive of 2% of Ketoprofen. The increase of Ketoprofen additive percentage contributed to more roughness in the surface especially at 2% percentage. However, the roughness was decreased with the increased additive above 2%. This can be demonstrated more obviously through Figs. 5a and 5b.

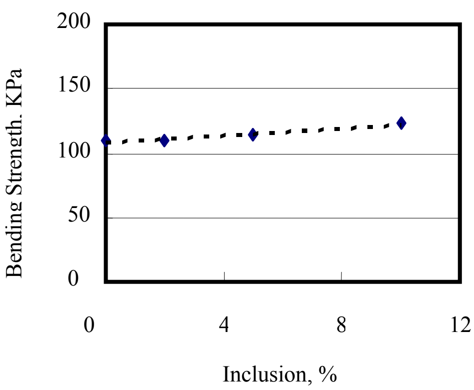

Fig. 2. Averaged bending strength.

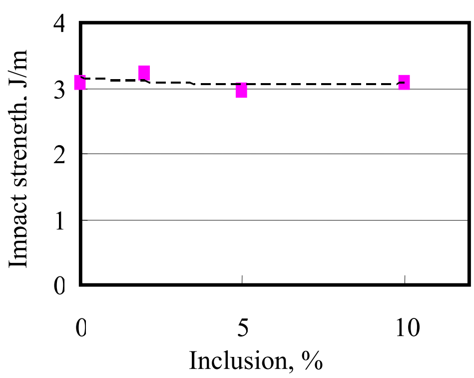

Fig. 3. Izod impact strength test results.

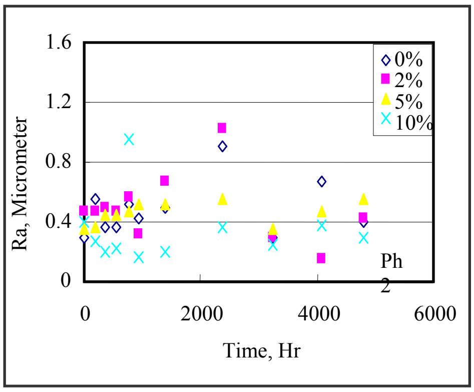

Fig. 4a

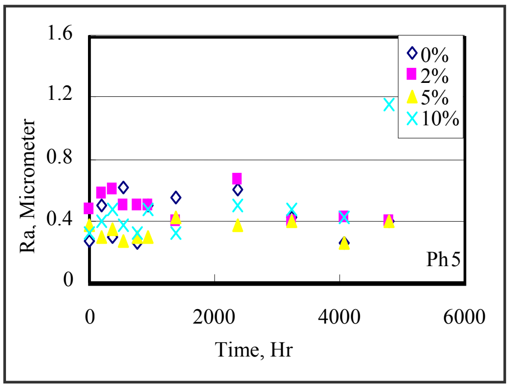

Fig. 4b

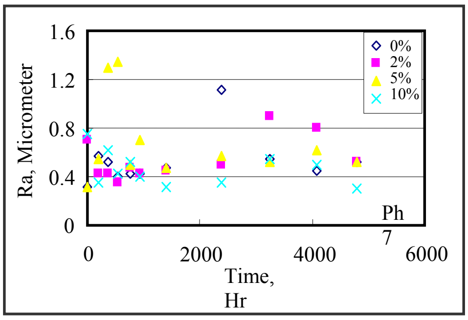

Fig.4c

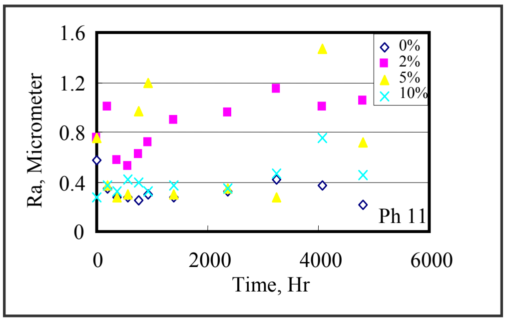

Fig.4d

Fig. 4. The effect of soaking time on surface roughness as expressed in terms of R_a at different pH values (2, 5, 7, and 11 in (a), (b), (c), and (d) respectively).

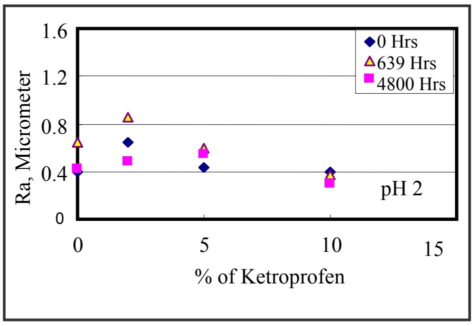

Fig. 5a

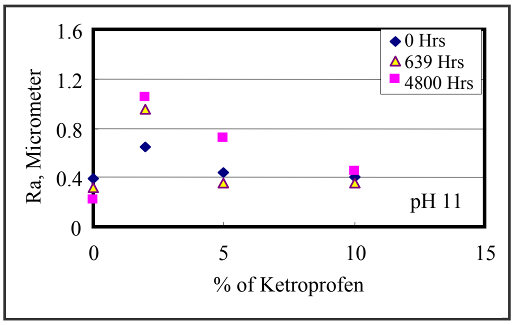

Fig. 5b

Fig. 5. The contribution of Ketoprofen percentage on surface roughness (R_a) at: (a) pH2 and (b) pH11.

4. Discussion

Figure 1 shows the average compressive strength as it is affected by the increase of Ketoprofen additive percentage. A general slight degradation of the compressive strength was displayed as shown. Including up to 5% of Ketoprofen in Acrylic resin did not contribute to a change in its compressive strength. Only specimens containing 10% Ketoprofen did show some degradation in their compressive strength (about 10%). Bending test results, shown in Fig 2., indicate that on the contrary of compressive strength, a slight improvement has occurred to specimens with the increase of Ketoprofen additive percentage. Bending strength was 4% higher with addition of 5% Ketoprofen, and increased by about 15% when the Ketoprofen percentage was increased to 10%. This may suggest that traction resistance was somehow enhanced with no similar effect on the sliding resistance to compressive loading at higher percentage of Ketoprofen (5% and up). Even though polymeric materials showed higher bending than compressive strength [21], further investigation is needed to clarify this issue and show the reason of the dissimilar behavior in deformation which accompanied the increase of Ketoprofen content in the Acrylic resin. Figure 3 shows the effect of the additive percentage on the fracture toughness in Izod impact. All specimens were soaked for one hour before performing tests. The results show that there is almost no effect of Ketoprofen additive increase on the fracture toughness of the specimens. As far as mechanical characteristics are concerned, Acrylic resin specimens containing around 5% of Ketoprofen showed overall improvement compared with specimens containing no Ketoprofen. Specimens containing 10% of Ketoprofen lost about 10% of their compressive strength and gained about the same fraction of bending strength with no obvious change in their fracture toughness. Less amounts of Ketoprofen (2%) did not contribute to any noticeable change in compressive, bending, and fracture toughness when added to acrylic resin specimens. Based on the results of compression, bending, and Izod impact, it can be stated that working with 5% Ketoprofen may be the most appropriate for components subjected primarily to compressive forces, however working with 10% additive is mostly appropriate to components subjected mainly to bending loading.

Figure 4 outlines the effect of the soaking time on the surface roughness of the specimens with different Ketoprofen additive percentages. The parameter R_a (which was taken as indicative parameter to surface roughness) was measured using Mitutoyo-surftest SV-402/414 instrument and expressed in μm. As a general trend, the increased Ketoprofen additive percentage contributed to some degradation of the surface smoothness especially at small additive values (2%). Increasing the Ketoprofen beyond 2% contributed to obvious improvement of smoothness of the surface as shown in Figs 5a, 5b. In other words, 2% Ketoprofen additive contributed to increase of the roughness with no soaking at all. Soaking time contributed to a slight degradation of the surface smoothness for specimens with 2% and 5% Ketoprofen. Specimens with Ketoprofen of 10% did not suffer from and loss of surface smoothness compared with specimens which did not contain Ketoprofen at all, even with severe soaking conditions. There was almost no loss at all in surface smoothness of specimens containing higher than 5% Ketoprofen. However, specimens with 2% and 5% showed obvious degradation of surface smoothness, especially at high severe medium (pH11). It can be stated that 2% Ketoprofen additive was not suitable from the point of view of surface smoothness especially with high corrosive medium (high pH values). Abu-Bakr, *et al* [22] showed that using solution with pH 2 was the most severe case as indicated by surface texture, however, that may be attributed to their use of different solutions for different pH values (orange juice, pH 3.83, cola drink, pH 2.62, whiskey, pH 4.04, and deionized water, pH 4.04).

5. Conclusions

Based on the foregoing study, it was found that adding the Ketoprofen (within the investigated additive percentages) does not show serious degradation of mechanical properties. However, working with additive percentage of 5% appears to be appropriate. Working with lower additive percentage may not be recommended especially from the point of view of surface smoothness. Based on experimental results, specimens of containing 2% Ketoprofen should be avoided, especially when they could be subject to higher corrosive environment (pH11). Higher values of Ketoprofen addition may cause slight loss in compressive strength (10%).

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الخواص الميكانيكية لمخلوط البولي ميثايل ميثاكريليت-كيتوبروفين في الدواعم والروابط

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المستخلص: يقدم البحث دراسة تجريبية لمعرفة أثر إضافة مادة مضادة للالتهابات (الكيتوبروفين) على مادة الإكريليك المستخدم بشكل واسع في عمل أطقم الأسنان الصناعية. وتضمن البحث تأثير إضافة تلك المادة بنسب متفاوتة (من ٠ إلى ١٠ %) على الخواص الميكانيكية (إجهاد الشد والثني والقصف) . وقد أخذ في الاعتبار تأثير النقع للعينات المحتوية على مادة الكيتوبروفين بنسب متفاوتة في محاليل حمضية وقاعدية على نعومة السطح. وقد تبين من تلك الدراسة أن إضافة مادة الكيتوبروفين قد أدى إلى تحسين إجهاد الثني بنسبة ضئيلة بينما لم يحدث تغيير يذكر في باقي الخواص الميكانيكية التي تم دراستها في البحث. وقد ظهر تأثير طفيف على نعومة السطح نتيجة لإضافة مـادة الكيتوبروفين وكذا أدى نقع العينات في المحاليل (من "pH 2" إلى "pH 11") إلى تغير طفيف في نعومة السطح وخاصة في العينات المحتوية على ٢% من مادة الكيتوبروفين.