Mar. Üniv. Ecz. Der.,
11 (1 - 2), 81 - 88 (1995)

J. Pharm. Univ. Mar.,
11 (1 - 2), 81 - 88 (1995)

BONDING MECHANISMS IN TABLETS

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INTRODUCTION

During the tabletting process, the application of pressure causes a reduction in the volume of the powder bed and a bonding together of the particles. Although these two phenomena are interconnected, most studies have concentrated on the examination of the relationship between applied pressure and the powder bed volume. This work has led to a greater understanding of the process, in particular, the deformation behaviour of powder particles under load. A knowledge of the compaction behaviour of a powder, whether by plastic flow or fragmentation, is an important factor in the formulation process.

In contrast, there has been only a limited amount of work carried out on the nature of the interparticulate bond. This is, in part, due to the difficulty in designing suitable experimental procedures. Recent work has attempted to elucidate the underlying bonding mechanisms in pharmaceutical tablets. This paper will review this work. A knowledge of the mechanisms is important in the design of physically strong tablets and their subsequent disintegration.

ASSESSMENT OF BONDING

The bonding achieved during the tabletting process is normally assessed by some measure of the mechanical strength of the tablet. Mechanical strength is not an absolute measurement and consistency must be achieved for valid comparisons to be made. The most

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useful approach is to measure the tensile strength of the tablet which ensures a single mode of failure and allows the dimensions of the tablet to be taken into account.

BONDING MECHANISMS

The bonding mechanisms believed to occur in dry powders subjected to pressure are solid bridges, mechanical interlocking and intermolecular attractive forces. These are discussed below.

Solid Bridges and Mechanical Interlocking

Solid bridges can be formed in compacted powders by diffusion, re-crystallisation and melting followed by solidification. Diffusion of material between surfaces is a "sintering" process which could occur on storage. Recrystallisation requires the presence of moisture. Melting could occur either as the result of high temperatures achieved during compaction or the lowering of the melting point of materials due to pressure. The latter is theoretically possible. Melting of particles has been observed during tabletting but surprisingly little work has been carried out to investigate this phenomenon. Mechanical interlocking is generally regarded as having a minimal contribution to the overall compact strength.

Intermolecular Attractive Forces

The intermolecular forces that are responsible for attraction between particles include coulombic forces between charged species, covalent bonds, hydrogen bonds and Van der Waals forces. Of these, the dispersion component of the Van der Waals forces are present in all molecules and, as shown in Table 1, contribute significantly to the total attractive energy. Only for small highly polar molecules is their contribution small. Thus, in assessing the contribution of attractive forces to the overall bonding, an assessment of the dispersion force contribution is a good starting point.

Two methods have been used to study this area, both of which involve screening out the forces. The first approach is to use lubricant films and the second is to change the continuous phase of the tablet i.e., to replace the air with a liquid.

1. Dispersion energy contribution to the total energy of interacting molecules.

Interacting Molecules	Dispersion Energy Contribution to Total Energy
Ne - Ne	100
CH_4 - CH_4	100
HCl - HCl	86
NH_3 - NH_3	57
H_2O - H_2O	24
H_2O - CH_4	87

Lubricant films

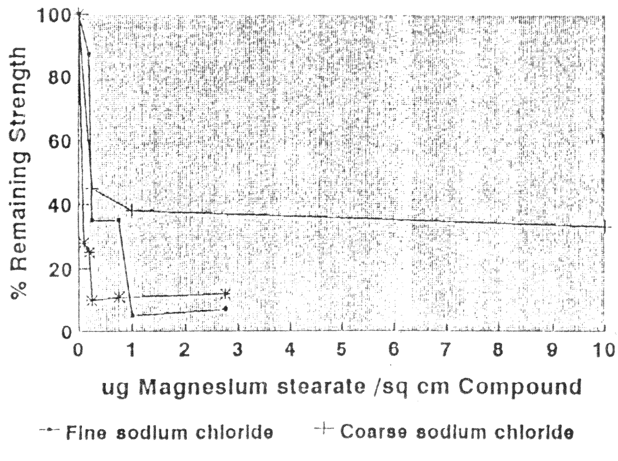
Magnesium stearate can be used as material for screening out intermolecular attractive forces. It is useful in this respect as it forms a film around substrate particles which is not disrupted by plastic flow. The film will be disrupted however, if melting and solidification occur. Because the film screens out the intermolecular forces but is penetrated by solid bridge formation means that measures of tablet strength with the films should give an indication of the relative importance of the two mechanisms. If bonding is purely by intermolecular forces, a strength close to zero would be expected. If a significant strength remains, then the possibility of solid bridges penetrating the film must be taken into account.

Figure 1 shows the % tablet strength remaining in compacts prepared with increasing quantities of magnesium stearate. For fine sodium chloride and sodium bicarbonate, the strength is reduced to almost zero at a magnesium stearate level corresponding to a molecular film coverage. However, a significant strength remains with the coarse sodium chloride indicating that this material bonds with a significant proportion of solid bridges.

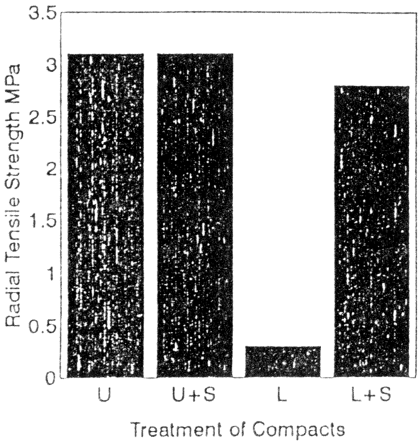
Further conformation of this can be obtained by endeavouring to remove the lubricant film by soaking the compacts in an appropriate solvent (Figures 2 and 3). Soaking in itself had no effect on the strength of the compact. Removal of the film in the case of fine sodium chloride produced an almost complete recovery of strength. For coarse sodium chloride, this was not the case, again pointing to another bonding mechanism, solid bridges, being involved (1, 2).

Change in continuous phase

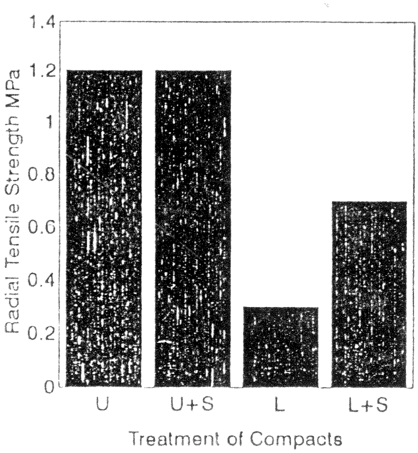
Dispersion forces always provide attraction between two particles of the same material, but that attractive force decreases with an increase in the dielectric constant of the intervening medium. Thus, measuring the strength of compacts in media of different dielectric constants provides another approach to studying the contribution of dispersion



1) Effect of lubricant concentration on remaining strength.



2) Tensile strength of compact exposed to soaking. U = unlubricated and unsoaked, U+S = unlubricated and soaked, L = lubricated and unsoaked, L+S = lubricated and soaked.



3) Tensile strength of compacts exposed to soaking.

Key - Figure 2.

forces to the overall bonding in tablets. Figure 4 shows the change in tensile strength of compacts of fine sodium chloride, lactose and Avicel in the presence of liquids of different dielectric constant (2). The strength is reduced as the dielectric constant increases, according to theory, and suggests that the bonding is mainly due to dispersion forces.

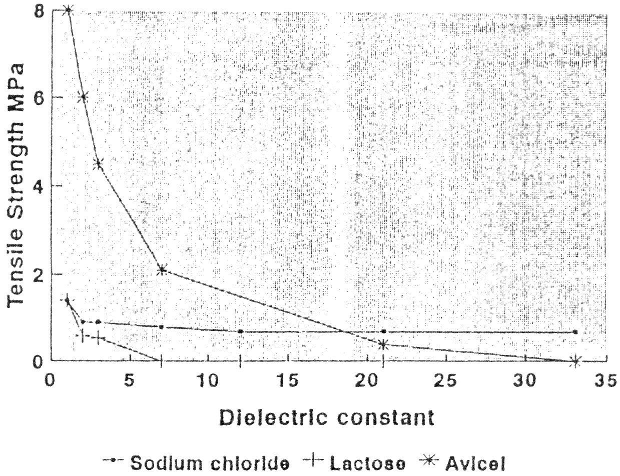
A more quantitative approach is to calculate the Hamaker constant, a measure of the dispersion force of attraction (3). This can be achieved via contact angle measurements on materials. The Hamaker constant changes in media of different dielectric constant. Figure 9 shows an example of this change compared to the change in tensile strength. The equivalence of the changes suggests that bonding in these compacts (PTFE) is by means of dispersion forces. Other materials behave in a similar manner (3).

Disintegration of compacts will be achieved through disruption of the bonds achieved during compaction. Table 2 shows that there is a relationship between the calculated Hamaker constant (H) and the disintegration time (DT) of compacts in various liquids.

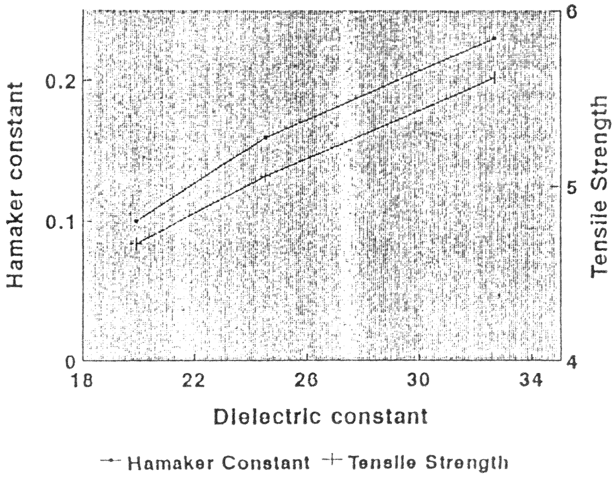
These results point to intermolecular forces as being the dominant bonding mechanism in tablets. Reduction in these forces in the presence of liquids is useful in examining disintegration.

2. Disintegration times (D.T.) of tablets in different liquids compared to the Hamaker constant (A).

Liquids	PVC A	PVC DT	Corvic A	Corvic DT	PTFE A	PTFE DT
Methanol	1.91	0.5	1.79	4	5.73	2.9
Ethanol	2.25	1	2.18	15	5.13	2.5
1-Hexanol	3.12	138	3.18	105	4.88	1.6
2-Methyl-butan-2-ol	3.60	>300	–	–	4.55	1.8



4) Effect of dielectric constant on tensile strength.



5) Relationship between Hamaker constant and tensile strength.

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