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Original Article
Published on 20/10/97

Metal Injection Molding in Orthodontics

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Keywords: orthodontic materials, metal brackets, hightechnology, MIM, CIM,

Introduction

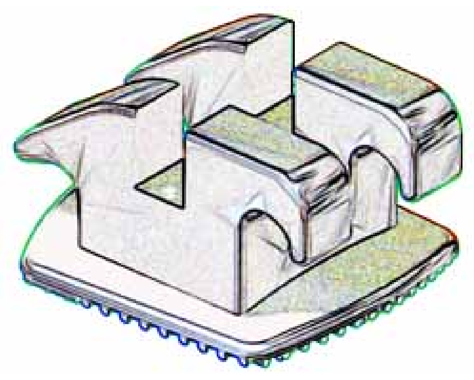
How do advancements in technological innovations affect our way of work in orthodontics?
There is no doubt that metallurgy plays a large role in clinical orthodontics; however, are we sufficiently prepared to fully understand the quality of the new industrial proposals in our field?

Should we or shouldn't we evaluate and try out the ever increasing number of high tech "gadgets"?

In the health sciences, it is our professional responsibility to our patients to constantly update our knowledge. In orthodontics, we deal mostly with appliances made of metal, ceramic, plastic, etc. It is important for orthodontists to have an understanding of the way these materials are produced, in order to prevent allergies and undesirable effects on our patients.
The new European laws on materials require orthodontists to keep the security document for each product purchased in the office, to assure patients the best care. Of course we are not expected to be experts in every field but it is certainly wise to learn about a wide variety of pertinent topics. At times, I personally feel somewhat unprepared when a new acronym reaches my ears. For example many orthodontic components today are produced by M.I.M. technology. M.I.M. stands for Metal Injection Molding.

M.I.M.

The M.I.M (Metal Injection Molding) and the C.I.M. (Ceramic Injection Molding) processes were conceived and developed in USA in the early 1980s. Even though the MIM process is one of the most promising powder metallurgy processes, its application was limited for a long time due to its high complexity and high cost. Ten years later industrial needs changed, and there was demand for high precision small parts by the aerospace, medical, optical, and computer fields. Today the demand for MIM products doubles each year (1).



The MIM process is especially suitable for small parts production in medium-high amounts. In fact traditional methodology is expensive because the housings are complicated, the materials are difficult to machine, and the starting feedstock is costly. In addition to the initial material cost, 50% to 75% of the material typically becomes scrap during machining. (2) As well, in many cases, MIM can facilitate the design of parts not previously achievable in metal. At the very least, it can streamline the manufacturing process and result in substantial benefits over traditional manufacturing methods. (3)

In the MIM process fine metal powders are combined with organic binders, lubricants, and dispersants to construct a feedstock for forming a shape in a mold. After the shape or part is molded, the organic components are removed from the structure by a solvent or thermal process and the remaining metal powder is sintered in a furnace at a high temperature.

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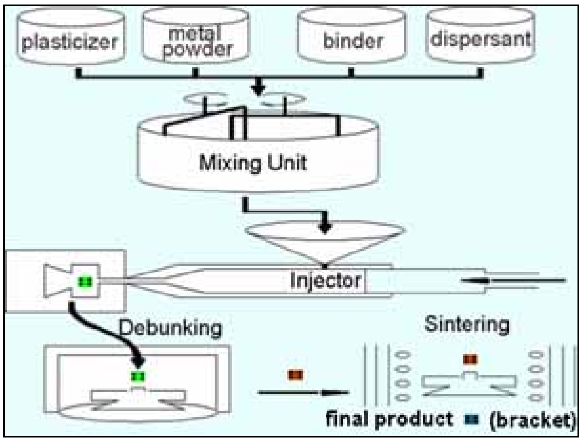

The final part is of high density and replicates the shape of the original part after molding, but it is typically 18% to 20% smaller because of shrinkage during sintering. As a result of that shrinkage, the use of metal injection molding in industry has been limited to manufacturing electronic packages that are 2 square inches. (2) In contrast to traditional sintering, MIM uses a large amount of binder, very refined metal powder (particle diameters are usually less than 15 microns), and a binder extraction technique which is very accurate.

Before starting a production with MIM, it is essential to determine whether the part is economically and physically suited to the process. This is often accomplished at the field sales level. Certain design changes may be appropriate in order to derive the maximum MIM cost and quality benefits. As in plastic injection molding, wall thickness should be uniform to avoid uneven shrinkage during sintering.

Raw material preparation (feedstock)

This is the first step. The metal powder or "metal dust" is mixed with the binder to obtain a homogeneous mix. For orthodontics components the breakdown is usually 55-65% metal dust and 45-35% binder. The binder is wax-based organic material and special machines assure a good mixed composition. This phase is essential to obtain quality in the final product. Orthodontic parts are usually created from stainless steel powder (316L, 430L) obtained by an atomization process and selected by grain size. The smaller particle in this case is 15 microns. The Ceramic Injection Molding (CIM) process instead uses Al_2O_3, ZrO_2, Si_3N_4, SiC, and Y_2O_3.

Injection molding

The next step is the molding process. There is no difference in technique from plastic injection molding. Certain devices are specifically created; however, it is critical that all parameters such as pressure temperature, injection speed, and so on, are extremely constant and controllable.
After molding, the part is called "green body" and it is relatively fragile. It is also 20% larger than the final product.

Debinding or debunking

The "green" parts are exposed to heat, solvent or a combination of the two in order to remove most (at least 90%) of the binder material. At the end the "brown" parts are approximately the same size as the green parts but are quite porous. This step is crucial and the residual 10% will be removed at the sintering phase. Several debunking processes are required for different binding materials.

Sintering

"Brown" parts are sintered in vacuum type furnaces or with minor success controlled atmosphere furnaces. This furnace reaches 1400 C° for MIM and 2000 C° for CIM process and they have sophisticated regulation systems to optimize all parameters and if necessary treat the final product thermally.
Here, they shrink 17 to 22% to nearly full density and are then complete. The vacuum furnaces are preferable to the others because the final product does not contain gas inclusions and it is more compact because the heat diffuses uniformly.

Conclusion

This process is quite long and delicate but allows for production of metals and alloys that cannot be used in traditional way as their melting temperatures are too high. Converting those stronger metals into a powder helps solve that problem. Powder metal parts can be made of some of the strongest elemental metals, as well as superalloys. And because they are formed to net shape, or near net, there is no money wasted on machined away scrap metal. This cost-saving feature is one reason for the increasing use of powder metal for making a variety of parts. The shape of a powder particle, which depends on the material and the way it was made, influences the density, surface area, permeability, and flow characteristics of the powder composition. By controlling these characteristics, the properties of the end-product can be altered.

Orthodontists use many appliances produced by MIM. These include brackets and NiTi palatal expanders. This technology allows the production of new alloys with different characteristics for different purposes. Metallic properties are essential in almost all orthodontic treatment and this MIM process could aid us tremendously in developing the quality of our materials.

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ACKNOWLEDGMENTS: The Authors would like to thank Leone S.p.A. for showing the MIM production details.

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