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SPECIAL SECTION

Contemporary Techniques for Denture Fabrication

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Abstract

This article reviews the fabrication of complete dentures and presents findings of recent technological studies that have relevance to current complete denture practice. In addition, summaries of two recent randomized controlled studies demonstrate the need for more deliberate prescription of impression materials.

Teeth may be lost through neglect or accident, or by virtue of orthodontic or prosthodontic treatment planning; they may also be missing for congenital or acquired reasons. People with missing teeth may opt to have them restored or not largely because of sociological, functional or, in the case of nonrestoration, for financial reasons.

How teeth are replaced largely depends on the level of dental and technological sophistication on offer. The splinting of teeth with thread or wire has an extensive history, and early Greek and Phoenician appliances were based on this concept. Etruscan technology was slightly more sophisticated; here, gold bands were applied around remaining teeth onto which a small tooth of bovine origin would be riveted as a replacement.[1] Until about the mid 1800s, ivory was the principal denture base material; teeth from the hippopotamus, predominantly, were sliced up, and appropriately sized pieces were carved by craftsmen with varying degrees of skill and success.[2]

When he prescribed dentures, Fauchard used neither impressions nor models. Ivory from the walrus or hippopotamus or the long bones of oxen were carved to form, simply through estimation, that is, via observing the shape of the mouth and measuring where required with a measuring device such as a pair of compasses. At a later stage, beeswax was used as an impression material. These prostheses were usually maintained in position by means of springs, which exerted constant pressure. In favorable cases, Fauchard made dentures maintained in position solely by atmospheric pressure.[3]

At the turn of the 20th century and for the next 50 years, dental technology developed, as did options for replacement of lost or missing teeth. In the latter half of the 20th century, as dentistry and dental technology developed, so the list of treatment options increased. Fixed prostheses became more predictable and more desirable. Where fixed replacement was contraindicated, removable prostheses became more elaborate, with precision attachments being used to enhance stability and appearance by potentially eliminating clasps. This was truly the pinnacle of the mechanical age of prosthodontics. More recently, the biological age developed, with the development of dental implants and also in consequence of their continuing and predictable success. It is surely incontestable that the gold standard for edentulous patients, advocated by Feine et al,[4] is to have at least a maxillary complete denture opposed by an implant-stabilized mandibular denture.

For many patients, dental implants may not be countenanced for a variety of reasons, and the purpose of this article is to investigate clinical and technical parameters of relevance to the fabrication of contemporary complete dentures.

For hundreds of years humankind has searched relentlessly to find a material capable of providing properties considered essential for use in the mouth. According to Anusavice,[5] an

ideal denture base material should, using relatively simple techniques, satisfy the following requirements:

- be insoluble and impermeable to oral fluids
- be easily pigmented and be color-stable
- be inert, that is, there should be an absence of taste and odor
- be esthetically pleasing and be transparent or translucent.

An appropriate denture base material should have adequate mechanical properties. For example, it should posses:

- a high modulus of elasticity so that greater rigidity can be achieved in comparatively thin sections of material
- a high proportional limit so that the denture will resist deformation
- appropriate strength—(frequently measured as transverse strength)
- sufficient resilience
- high fatigue strength
- low sorption and solubility and be dimensionally stable in or out of oral fluids
- appropriate hardness with good abrasion resistance so the material will not wear appreciably, but will take a high polish
- high impact strength, to resist unavoidable accidents.

From a physical perspective, denture base materials should demonstrate thermal expansion compatible with that of the prosthetic tooth material, high thermal conductivity, low density to assist in the retention of the upper denture and a softening temperature above that of hot food and liquids in the mouth. Currently, no denture base resin on the market is capable of fulfilling all the ideal requirements. In this article, attention is confined to complete dentures exclusively.

The fabrication of complete dentures is a unique combination of art and science. This presentation shall address clinical aspects of relevance to the fabrication as well as technological components of complete dentures.

Technical aspects of fabrication

While CAD/CAM techniques currently have much to offer for fixed prostheses and perhaps shortly for removable partial dentures, the possibility of these techniques being on offer for complete dentures remains remote.

In essence, the fabrication of complete dentures has involved the construction of replacement teeth in a wax template (the trial denture) and enclosing this assembly in an investing material before replacing the wax with a more permanent denture base material. In the 1850s, the material of choice was Vulcanite, and this was replaced by poly (methy) methacrylate (PMMA) following its development by Hill in 1931. Kalodent was the first marketed material (in 1935) supplied as a polymer thermoformed under pressure. Also in 1935, a patent was taken out by Kulzer in Germany for a denture base resin, the polymer of which was "softened and joined" by the action of monomer.[6]

Itemizing the chemistry of PMMA is not essential to this article, but it remains a sobering thought that many laboratories currently use techniques promulgated in the 1930s. In essence, this consists of using paired flasks to form molds of the trial dentures. The next stages are:

(i) boiling out the wax
(ii) mixing a "dough" of PMMA polymer/copolymer powder with monomer
(iii) performing a trial closure
(iv) processing in a water bath for a controlled period of time
(v) devesting and polishing of the processed dentures.

Over the years, refinements have been carried out, but the system tends to be laborious and relatively prone to errors of processing and carries a risk of contact dermatitis to dental technicians.

Several studies have indicated that any lack of dimensional accuracy in denture bases produced during processing procedures is probably a consequence of one or more factors.[7]

Thermal shrinkage of acrylic resin is considered to be primarily responsible for the linear shrinkage in heat-cured acrylic resin systems. Earlier versions of injection-molded systems to process acrylic resin-based dentures were perceived to be less consistent than conventional compression-molded techniques. Recent studies, however, have indicated that complete dentures processed by 21st century injection molding techniques exhibited greater accuracy and dimensional stability than those processed via standard compression processing.[8]

For these reasons, injection-molding processes have been introduced, and these, in conjunction with newer materials, have produced results that would appear to indicate, on the grounds of evidence-based dental technology, that newer techniques are superior.

For example, El-Khartia[9] carried out a study to determine if the processing technique in any way influenced the surface of acrylic denture bases. Fifteen maxillary primary casts were collected, and four alginate impressions were made for each cast. Impressions were poured, and master casts constructed. In all, this resulted in 60 denture casts on which 60 maxillary denture bases were prepared in dental wax.

The wax bases were invested, and the wax eliminated from the molds. Fifteen specimens were assigned to each of four groups:

- Group 1 was subjected to conventional processing technique using Trevlon (Dentsply, Dreiech, Germany) acrylic resin.
- Group 2 was subjected to an injection-processing technique using PalaXpress, (Heraeus Kulzer, Wehrheim, Germany) acrylic resin.
- Group 3 was subjected to a conventional processing technique using Paladon 65 (Heraeus Kulzer) acrylic resin.
- Group 4 was subjected to an injection-processing technique using Paladon 65 acrylic resin.

The same dental stone was used throughout the study, and therefore the main variable was the method of processing. Trevlon is perhaps the most commonly used heat-polymerized acrylic resin for conventional processing in the United Kingdom; PalaXpress is a novel acrylic resin material, which is autopolymerizing and is injection-processed; and Paladon 65

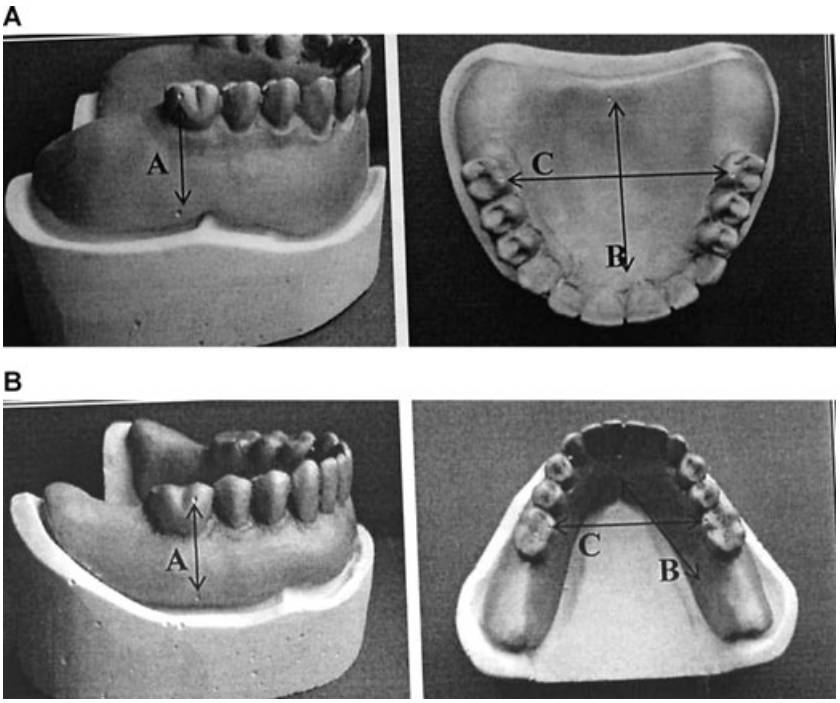

Figure 1 Illustration of control master dentures, with six points indicated (A) maxillary denture, (B) mandibular denture.

is a heat-polymerized acrylic resin, which may be processed conventionally or by injection.

The study demonstrated that denture bases processed via the injection technique exhibited a smoother surface than those processed via a conventional processing technique. The surface roughness data obtained for Rmax, Rz, and Ra and the results for PalaXpress and Paladon 65 (injection-processed) were highly significant when compared to Trevlon. Those for Paladon 65 (conventionally processed) were statistically significant. Just how clinically relevant this difference is, however, remains to be assessed.

Al-Dharrab[10] made replica dentures of a control complete denture constructed in cobalt-chromium alloy. Six reference points were made on the control dentures (Fig 1), and replica dentures were fabricated using a conventional technique and also an injection-molded technique (Palajet, Heraeus Kulzer GmbH, Hanau, Germany); the distances between the reference points were measured and compared to the control.

The six points drawn and the lines joining them are outlined in Table 1.

In all, six groups were analyzed (five maxillary and five mandibular dentures in each group except the metal control group):

(1) Metal control dentures.
(2) A standard duplicated injection-processed group (using PalaxPress). Here, the metal dentures were duplicated using a duplicating silicone (Flexistone, Detax Gmbh, Ettlingen, Germany) in the Palajet flasks, and the metal dentures removed before processing the duplicate dentures under injection.
(3) A conventional (heat-processed) group. The steps used here were exactly as per Group 2 except that the acrylic dentures were processed in Meliodent (Heraeus Kulzer) conventionally.
(4) A cold-cured resin group of dentures using the technique advocated by Murray and Wolland[11] (i.e., a metal duplicating flask) using alginate (Xantalgin, Heraeus Kulzer) as an investment.
(5) A cold-cured resin group of dentures using the technique advocated by Murray and Wolland[11] (i.e., a metal duplicating flask) using laboratory (silicone) putty (Zetalabor, Zhermack, Rovigo, Italy) as an investment.

Table 1 Reference points and lines on the maxillary and mandibular dentures

Line	Maxillary denture	Mandibular denture
A	Vertical line joining two points on the buccal side of the maxillary first molar and a point near the border of the peripheral roll	Vertical line joining two points on the buccal side of the mandibular first molar and a point near the border of the peripheral roll
B	Antero-posterior line joining two points, one near the center of the posterior border and the other in the center near the incisive papilla area	Diagonal line joining two points, one on the lingual flange, just distal to the first molar tooth and a point in the lingual flange in the midline.
C	Horizontal line between the mesio-palatal cusps of the maxillary first molar teeth	Horizontal line between the mesio-lingual cusps of the maxillary first molar teeth

(6) A cold-cured resin group of dentures using the technique advocated by Duthie and Yemm,[12] that is, plastic stock trays using silicone putty (Zetalabor) as an investment.

The three lines for all dentures examined (52 in all) were measured using digital calipers, and the means and standard deviations recorded. Each specimen was measured three times, and the validity of the measurements determined by using a noncontact 3-D digitizer (VIVID 910, Konica Minolta, Tokyo Japan).

Any change between the control dentures and the replicated dentures represents a dimensional change, and the potential changes were measured at four stages:

(1) initial reading of control maxillary and mandibular dentures,
(2) immediately after processing of the duplicate (acrylic resin) dentures,
(3) after storing the specimens in 37°C distilled water for 1 week,
(4) after storing the specimens in 37°C distilled water for 1 month.

The following salient findings were reported:

- The use of Flexistone resulted in improved dimensional stability of processed dentures when compared to silicone putty or alginate.
- Dentures processed in PalaXpress had less dimensional changes than the conventional group, when Flexistone was used as an investment.
- Alginate resulted in greatest shrinkage.
- Vertical dimensional changes were greater than horizontal changes.

The implications of these technological findings may well result in changes in how replica dentures are prescribed clinically and technically.

Clinical aspects of fabrication

The fabrication of complete dentures has a relatively short history of hundreds of years—minor in comparison to the history of tooth loss. There is, however, a clear understanding of most of the anatomical, physiological, and psychological factors related to this branch of prosthodontics. It is generally agreed that to be successful, complete dentures must satisfy the demands of support, retention, and stability. Support is obtained from underlying bone and covering soft tissues. Retention is achieved essentially via a peripheral seal, while stability is a paradigm of muscle balance and occlusal balance.[13–15] The latter is achieved in an integrated manner, between the definitive impression, registration technique, tooth selection, and patient neuromuscular control. In the main, retention and support are influenced by the definitive impression, and this is of paramount importance where the conventional mandibular complete denture is concerned.

Scientific evaluation of many of the clinical procedures tends to be anecdotal and not evidence-based. With this in mind and given the need to address contemporary evidence-based (clinical) care, this article addresses two areas where clinical techniques have been researched, namely impression techniques and selection of occlusal forms.

Table 2 Digital analog box used to record patient opinion of each mandibular denture

Score awarded per denture	Definition offered for score
1	Most comfortable
2	Neither 1 nor 3
3	Least comfortable

In the first reported cross-over randomized controlled trial in complete denture prosthodontics, McCord et al[16] sought to determine if the nature of the impression material, used to record the mandibular definitive impression, influenced the outcome of the treatment as measured by patient opinion.

Following ethical committee approval for the study, 11 edentulous patients (five women and six men) were enrolled into the study. All had been edentulous for at least 5 years and all had Atwood Order V mandibular ridges.[17] Each patient was prescribed a maxillary complete denture and three mandibular dentures; the replacement dentures for each patient were prescribed to the same occlusal vertical dimension. Each of the three mandibular dentures for each patient had identical forms of occlusal and polished surfaces via the use of plaster indices; the principal difference between the three mandibular dentures for each patient was in the nature of the master cast obtained from one of three impression materials. All dentures were processed via an injection-molding technique, and each mandibular denture was worn for 1 month. Reviews were made after 1 week and at 1-month post-delivery. At the 1-month review the patients were asked to complete a questionnaire, which determined their satisfaction with their dentures, the mandibular denture in particular. The process was repeated for each of the three mandibular dentures, and each patient was asked to quantify perceptions of the mandibular dentures using a digital analog box (Table 2).

The clinical procedures involved were those advocated by Ogden.[18] Three types of impression material were used to record the definitive mandibular impression:

(1) A light-bodied poly(vinyl siloxane) material (Provil, Heraeus Kulzer, Dormagen, Germany).
(2) A two-paste system of zinc oxide eugenol (SS White Mfg., Gloucester, UK).
(3) An admix of impression compound and tracing compound.[19]

The maxillary master casts were transferred to the articulators via a facebow transfer, and all intermaxillary registrations were recorded via a central bearing device (PTC UK Ltd., Bolton, UK).

All dentures were fabricated and processed by one technician who alone knew the "code" for which impression material produced which impression surface (identified on the polished surface of the denture). The order in which each of the three mandibular dentures was supplied to the patient was determined from a table of random numbers (Table 3).

Table 3 Which dentures were allocated to each patient

Patient no.	Inserted first	Inserted second	Inserted third
1	C	T	S
2	C	S	T
3	T	C	S
4	S	C	T
5	T	S	C
6	C	T	S
7	C	S	T
8	C	S	T
9	C	S	T
10	T	C	S
11	S	C	T

T = definitive impression recorded in zinc oxide eugenol;
S = definitive impression recorded in Admix;
C = definitive impression recorded in poly(vinyl siloxane).

The three types of materials used to record the definitive impression plus the order of insertion were each addressed statistically by entering data as either a) most preferred or not or b) least preferred or not. A general estimating equation (GEE) model was applied to each of these dichotomous variations using the "xtgee" command in Stata 8 (like logistic regression) with the impression material and independent order variables.

It was found:

(1) that the dentures processed on casts poured into the zinc oxide eugenol impression were never the denture that was most preferred and was least preferred in 8 out of 11 occasions
(2) that the dentures processed on casts poured into the Admix impression were the denture that was most preferred in 7 of the 11 occasions and was least preferred on 1 occasion
(3) that the dentures processed on casts poured into the poly(vinyl siloxane) impression were the denture that was most preferred on three occasions and was least preferred on two occasions
(4) there was no statistically significant difference between dentures coded "S" and "C," but there was a highly significant difference between the dentures coded "T" and the other two codings.

Clearly, then, clinicians do need to reflect on what impression material is used to record the mandibular impression, especially the atrophic mandible, if some degree of predictable successful outcome is to be realized.

A similar study was performed by El-Khartia.[9] She conducted a randomized controlled study on 27 patients using six impression materials (vide infra) to make six master models for maxillary complete dentures. On each of these master casts, a PMMA base was fabricated using an injection-molding technique (Palajet). Ethical approval was sought and granted.

The six impression materials studied were:

(1) Irreversible hydrocolloid (Xantalgin, Heraeus Kulzer)
(2) Poly(vinyl siloxane) (Provil light, Heraeus Kulzer)
(3) Polyether (3M ESPE, St. Paul, MN)

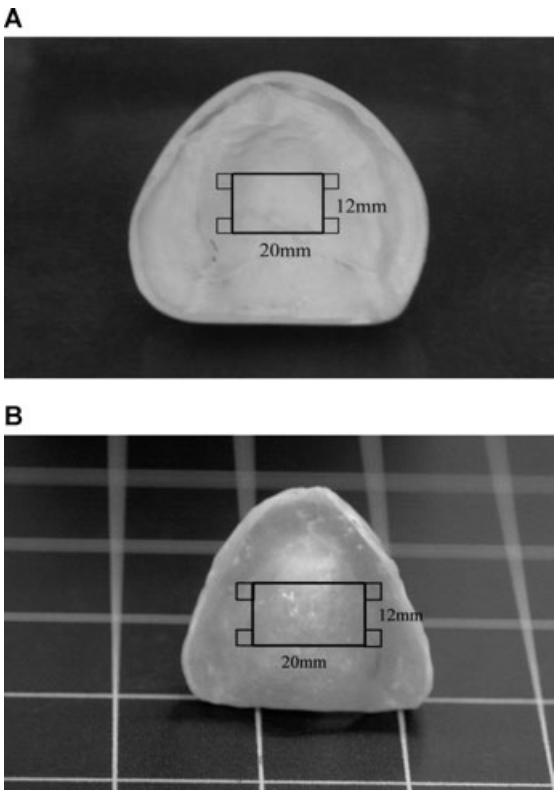

Figure 2 The standardized area selected for measurement by scanning (A) on the stone cast and (B) on the denture base.

(4) Polysulphide (Permalastic, Kerr Co. Ltd, Peterborough, UK)
(5) Zinc oxide eugenol paste system (SS White Group)
(6) Plaster of Paris (Snow White, Kerr).

On the mid-palatal surfaces of all of the master casts and the impression surface of all 162 denture bases, a rectangular box (20×12 mm^2) was drawn and at each angle four small square areas were drawn (Fig 2), and these were all scanned (10 times per area scanned) on a Perthometer S8P machine to measure surface roughness.

The results indicated that denture bases, when processed on casts poured onto impressions recorded in plaster of Paris, possess the highest degree of surface roughness. Denture bases processed on master casts poured onto the other five impression materials used to record definitive impressions showed no statistical significant difference in terms of their surface roughness.

A positive correlation was found between stone casts and PMMA denture bases for all impression materials tested in terms of surface roughness.

The effects of the nature of the occlusal surface of posterior teeth on the outcome of complete dentures were recently reported by Sutton and McCord.[20] They performed a randomized controlled study (for which ethical approval had been obtained) on 45 patients. Each patient received three sets of complete dentures, which were identical in every aspect except the nature of the occlusal surfaces of the posterior teeth. In essence, the teeth supplied had either:

- Zero degree posterior teeth
- Anatomic posterior teeth (33° cuspal angle—Basic 8, Heraeus Kulzer)
- Lingualized occlusion teeth.

Each set of complete dentures was worn for 8 weeks, after which the participants filled in an Oral Health Impact Profile-20 EDENT (OHIP-EDENT).

The participants were not informed of the nature of each set they were given, and after each 8-week period, the clinicians retained control of the other two sets. Patients were allocated the different dentures in a randomized manner. In essence, it was discovered that no statistically significant difference was recorded between dentures with lingualized occlusion teeth and anatomic teeth.

In contrast, patients complained of more oral discomfort and difficulty in eating when 0° teeth were worn.

Summary

There can be no doubt that we are at, if we have not already passed, a prosthodontic crossroads where we have evolved from a mechanistic approach to clinical care to a biological era of preventive prosthodontics. Some of the demand for sophisticated treatment has come from media coverage, especially the electronic media. Rapidly advancing IT developments will supersede current technologies, but all must be developed with a conscious demand for evidence-based care. Another potential problem is the diminution in quantity of prosthodontic teaching in undergraduate schools.[21] This can only place greater demand on graduate programs to supply the training required in prosthodontics to meet the need for the large aging/elderly population of the world. It is also worrying that, in the United Kingdom at least, the number of technicians pursuing complete denture prosthodontics is alarmingly low, and those who are doing so are hardly using advanced techniques.

The onus is on us to fuel the fires of prosthodontic research and to cultivate an ethos of clinical and technological excellence.

This must be balanced by knowledge of improvements in dental technology and also randomized controlled clinical trials. On the evidence of studies reported in this article, we know that the outcome of complete denture provision is determined by proficiency in the dental laboratory and the need to be more selective in how we manage our impressions and in the occlusal forms we prescribe.

The challenge is to achieve an acceptable result in an increasingly challenging clinical scenario.

TIPS FOR THE PRACTICING DENTIST

1. When recording definitive impressions for maxillary complete dentures, always ensure the tray is nonperforated, as you cannot otherwise demonstrate a peripheral seal.
2. After you assess the nature of the ridges (especially the atrophic mandibular ridge), ensure you select an appropriate impression material—it will make a difference to the outcome.
3. When prescribing replica or template dentures, how you replicate the dentures will determine the accuracy of the resultant denture.

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