MATERIALS, TECHNOLOGICAL PROCESSES AND DEVICES USED FOR CUSTOM IMPRESSION TRAYS FABRICATION

Minsk BSMU 2020

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КАФЕДРА ОБЩЕЙ СТОМАТОЛОГИИ

МАТЕРИАЛЫ, ТЕХНОЛОГИЧЕСКИЕ ПРОЦЕССЫ И УСТРОЙСТВА, ИСПОЛЬЗУЕМЫЕ ДЛЯ ИЗГОТОВЛЕНИЯ ИНДИВИДУАЛЬНЫХ ОТТИСКНЫХ ЛОЖЕК

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Учебно-методическое пособие

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INTRODUCTION

Custom impression trays are special medical devices made individually for a specific patient and used for further impression. They are widely used in dentistry nowadays.

There are three methods of custom impression tray fabrication in a dental laboratory. Each of them involves the use of different materials, technological processes and devices (Fig. 1).

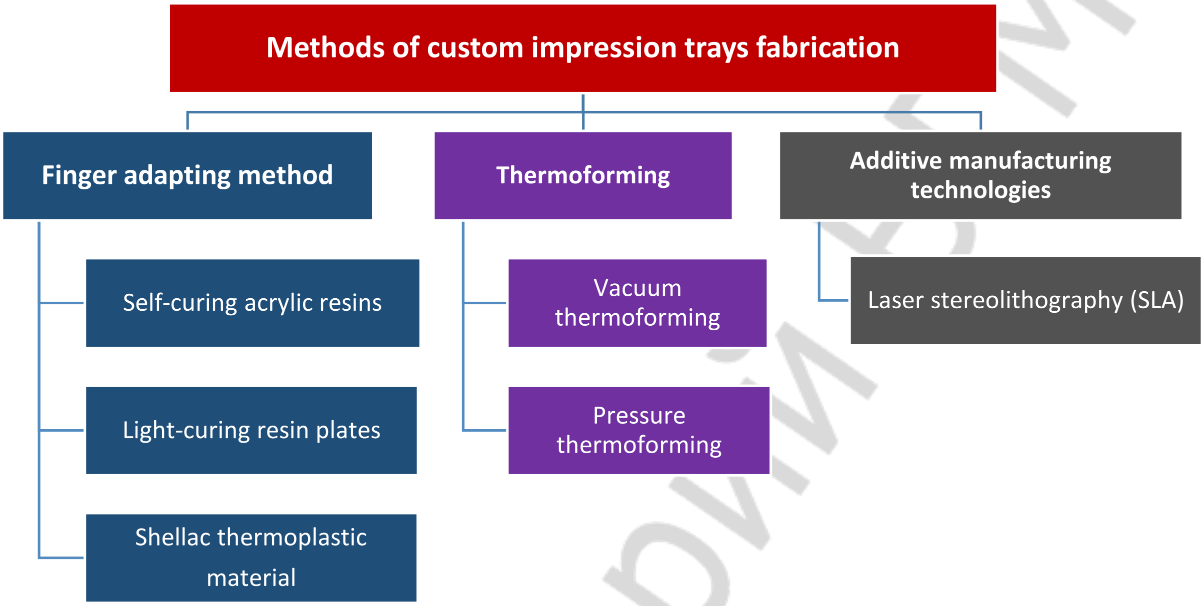


Fig. 1. Methods of custom impression trays fabrication with the use of different materials, technological processes and devices

THE CUSTOM IMPRESSION TRAYS FABRICATION BY FINGER ADAPTING METHOD

Compression molding technique and injection molding technique can be potentially used in the custom impression trays fabrication. These processes include wax modeling of the tray, the use of the split flask or a special flask with sprues system and syringe press. However, the wasting of time and the need to use special equipment for these technological processes caused the use of more simple methods of custom impression trays fabrication, such as finger adapting method.

Finger adapting dough method involves polymer-monomer dough adaptation with fingers on the diagnostic cast, trimming the excess material and handle formation. This technology is used in the custom impression tray fabrication with self-curing acrylic resins, light-curing resin plates and shellac thermoplastic materials.

Self-curing acrylic resins («Протакрил-М» («СТОМА», Ukraine), «Villacryl IT» («Zhermack», Italy), «SR Ivolen» («Ivoclar Vivadent», Liechtenstein) and others) are commonly used in custom impression trays fabrication by finger adapting dough method (Fig. 2).

Fig. 2. Self-curing acrylic resin for custom trays fabrication

The powder of self-curing acrylic resin includes polymethylmethacrylate, calcium carbonate (filler), benzoyl peroxide (initiator) and pigments. The liquid includes methyl methacrylate, hydroquinone (inhibitor) and tertiary amine (activator).

The sequence of the custom impression tray production by finger adapting dough method includes the following steps: diagnostic cast fabrication, covering gypsum model with isolating liquid, drawing of the tray borders, mixing of polymer and monomer, dough adapting, handle addition and trimming the tray.

The diagnostic cast is poured with type II of gypsum products on base of the preliminary impression with further trimming. In the presence of undercuts, it's necessary to block-out them by baseplate wax.

The borders of the future custom tray are marked with a chemical pencil deviating 1–2 mm from the deepest part of the vestibule of the mouth, bypassing the frenulums and buccal frenums (Fig. 3, a). Custom tray border molding can be done by thermoplastic impression material or non-aqueous elastomers in putty or high viscosity at the time of functional tests, if the borders are short.

Gypsum model should be covered with isolating liquid based on an alginate solution. Polymer-monomer dough is prepared by mixing liquid and powder in recommended proportions by the manufacturer. Proper mixing of the resin is carried out in the chemical-resistant bowl with spatula. The acrylic dough should be immediately kneaded for 1 minute by fingers in gloves from polyethylene for hands protection. Custom impression tray is formed by adapting the dough to the cast. The excess material is trimmed away with a knife on the previously marked borders. The tray handle is produced from excess of dough. Except for the handle in the anterior part, it is necessary to form two finger rests in the area of the missing the first molars in the mandibular impression custom tray (Fig. 3, b).

The entire time of polymerization for modern self-curing acrylic resins is on the average 8–12 minutes from the moment of mixing powder and liquid.

After polymerization of the material individual custom trays are trimmed and then they are ready for use in the clinic (Fig. 3, *b*, *c*).

a ***b*** ***c***

Fig. 3. Mandibular diagnostic gypsum cast with marks of impression custom tray (*a*), mandibular impression custom tray (*b*) and maxillary impression custom tray (*c*), fabricated by finger adapting dough method from self-curing acrylic resin

Block-out is carried out with baseplate wax with holes formation on the gypsum cast, that create limitations in the dipping of the tray with the impression material, in cases when it's necessary to form a gap for the impression material between the custom impression tray and the mucous membrane (Fig. 4).

Fig. 4. Undercuts on the mandibular gypsum cast blocked out with baseplate wax with holes for finger rests formation on the inner surface of the custom impression tray

Sprinkle on method is one of the methods used in the fabrication of custom impression tray (I. Lebedenko and others, 2005). Separating medium is applied to the cast, then the monomer is applied to the cast using eye dropper and the polymer is carefully added until a sufficient thickness is gained over the entire surface of the cast. Plastic polymerization is carried out in a pressure polymerizer at a pressure of 3 atm.

Custom impression tray fabrication using self-curing acrylic resins on the gypsum cast has a benefit in the time of production and in the cost of the work. However, this method doesn't have priority, because of the toxicity of the material during long-term contact with it and its shrinkage.

Light-curing resin materials are used for the fabrication of custom impression trays by finger adapting dough method. This material consists of a matrix of polyfunctional methacrylates and inorganic fillers and available in the form of soft standard plates for the upper and lower jaws with a thickness of 1.5–3 mm (Fig. 5).

Fig. 5. Light-curing resin plates for the fabrication of custom impression trays

Light-curing resin plates may be polymerised with any kind of UV device (wavelength of 365 nμ). The device consists of the retractable tray for installing a gypsum cast with a custom impression tray (Fig. 6).

Fig. 6. UV device for polymerization of resin plates ПМУ 1.0 (Аверон, Russia)

The borders of the future custom tray are marked (Fig. 7, *a*) and then block-out is carried out with baseplate wax with a thickness of 1,5–2 mm to form a necessary space for the impression material (Fig. 7, *b*). Light-curing resin plate is moulded onto the model (Fig. 7, *c*). The excess material can be used to form the handle (Fig. 7, *d*).

a ***b*** ***c*** ***d***

Fig. 7. The sequence of the custom impression tray fabrication with light-curing resin material by finger adapting method (A guideline for excellent impressions in theory and practice in collaboration. B. Wöstmann, J. M. Powers. 3M ESPE)

The resin plate is polymerized in a special UV- or blue-light device (Fig. 6). The curing time of the material with a thickness of 1.5 mm is 3 minutes. In case with a larger thickness of the custom impression tray, it is recommended to remove the plate from the gypsum cast and to repeat polymerization of the reverse side of the tray. The custom impression tray fabricated with light-curing resin material by finger adapting method requires minimal trimming (Fig. 8).

Fig. 8. The custom impression tray fabricated with light-curing resin material Elite LC (Zhermack, Italy) by finger adapting method

Along with self-curing acrylic resins and light-curing resins, shellac thermoplastic materials can be used for the fabrication of custom impression tray by finger adapting method. Thermoplastic base plates contain shellac, stearic acid, talc (50–60 %) and mica. Shellac base plates Tessex AL (SpofaDental, Czech Republic) contains aluminium admixture. The material is produced in the form of rigid plates for upper and lower jaws with a thickness of 1.5 to 3 mm (Fig. 9).

Fig. 9. **S**hellac thermoplastic base plates for the custom impression tray fabrication by finger adapting method

The baseplate is heated in the hot water or by steam jet machine, the softened baseplate is taken and adapted to the cast with hands, then the excess is trimmed and a handle is formed (Fig. 10). The shellac base plate hardens and retains its shape stability at room temperature.

Fig. 10. The custom impression tray fabricated with shellac base plate by finger adapting method

THE CUSTOM IMPRESSION TRAYS FABRICATION WITH POLYMER MATERIALS BY THERMOFORMING

The devices for thermoplastic polymer heating with further adapting on the gypsum cast are used for vacuum thermoforming or pressure thermoforming.

Vacuum forming machine is used for mouthguard thermoforming (Fig. 11). In a wide variety of these devices, there are two types that differ in the shape of the mounting frame for fixing thermoplastic material: square or round. The shape of the frame determines the appropriate shape of the resin sheets to be fixed in it and then formed.

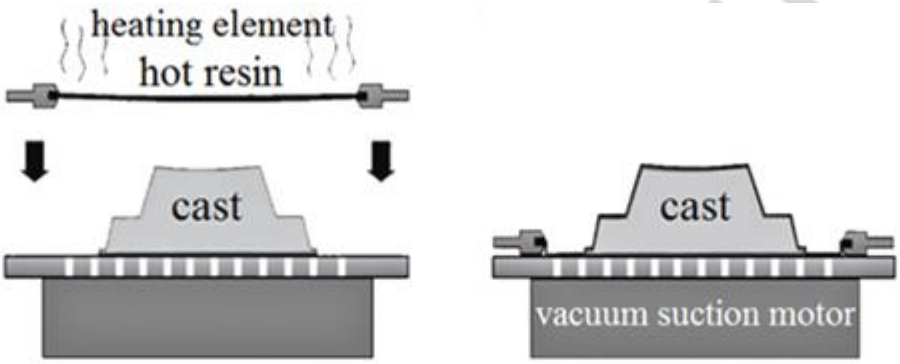
Fig. 11. Vacuum forming machine:
a — heating element; *b* — top and bottom frames with two handles and plastic retainer; *c* — hexagonal post; *d* — gypsum cast; *e* — perforated plate; *f* — vacuum suction motor; *g* — vacuum switch to turn on and off the heating element and vacuum suction motor

Styrene-butadiene, polypropylene or polystyrene sheets with a thickness of 2, 3 or 3.8 mm are used for thermoforming of custom impression tray (Fig. 12, *a*). A porous material (foam) with a thickness of 3.0 mm is possible to use for forming the place for the impression material (Fig. 12, *b*). The foam material is applied to the surface of the gypsum cast, which allows creating a place for the impression material after forming and a textured surface that provides a good mechanical adhesion of the impression material with the tray.

The principle of work of the vacuum forming machine is shown in Fig. 13 and includes the following steps: sheet heating (Fig. 13, *a*) and its molding to the cast by vacuum suction motor (Fig. 13, *b*).

a ***b***

Fig. 12. Styrene-butadiene sheets for thermoforming of custom impression trays (*a*) and the foam material for isolation of the gypsum cast (*b*)



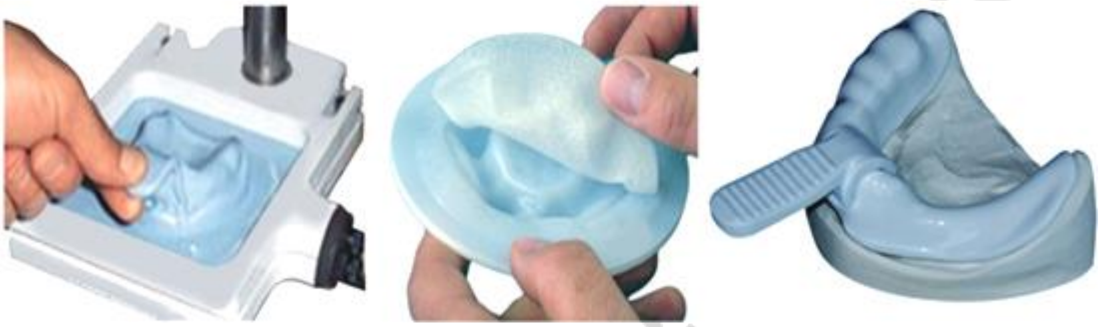
a ***b***

Fig. 13. Scheme of custom impression trays thermoforming with resin sheets

The borders of the custom tray are marked. In the presence of undercuts, it's necessary to block-out them by polydimethylsiloxane, which is resistant to high temperatures. The cast is placed in the center of the perforated plate. The foam material is applied to the surface of the gypsum cast, which allows creating a place for the impression material.

Thermoplastic sheet is clamped between top and bottom plates with a retainer after preparing the cast. The sheet frame is moved at the top of the post to the maximum upper position relative to the heating element and the vacuum switch is turned on, the sheet is heated to a plastic state. The heating time depends on the power of the vacuum forming machine, the type of resin and the thickness of the sheet. It's possible to control the level of heating of the material by visually evaluating the sagging of the sheet in the frame. It means that the material is transitioned to a plastic state, when the sheet is sagged 3–4 cm.

The vacuum suction motor is turned on and the frame sheet is pulled down over cast after transition the polymer material to a plastic state. The hexagonal post keeps the sliding frame from turning. The vacuum suction motor creates a vacuum between the sheet and the perforated plate, that's why the cast and the perforated plate are firmly covered by the sheet (Fig. 14, *a*). After 20–30 seconds of the vacuum work, it's possible to adapt additionally the tray to the cast with a wet tissue with working vacuum. The vacuum suction motor is turned off and the custom impression tray is cooled on the gypsum cast after forming. It is recommended to place the tray and cast in cold water to speed up the cooling process. The custom impression tray is removed from the porous material after cooling (Fig. 14, *b*), the tray is trimmed around outline with laboratory bur, the edges are smoothed out and the plastic handle is attached with a special glue (Fig. 14, *c*). The handle of the tray can be formed by pulling the warm polymer material in the anterior part with tweezers.



a ***b*** ***c***

Fig. 14. The custom impression tray fabrication in the vacuum forming machine (a), the removing of porous material from the tray (b), custom impression tray with the handle after fabrication (c)

Pressure thermoforming is used in fabrication of the custom impression trays along with vacuum thermoforming. Dental pressure thermoforming machines are used for these purposes (Fig. 15). They provide digital heating of polymer material and produces excellent internal adaption on gypsum cast by compressed air at a pressure of up to 6 atm.

Fig. 15. Pressure thermoforming machine Drufosmart scan (Dreve Dentamid GmbH, Germany)

The principle of work of the pressure thermoforming machine is shown in fig. 16 and includes the heating of the polymer material fixed in the plate reception (Fig. 16, *a*), installing the pressure chamber (Fig. 16, *b*), covering the gypsum cast by the thermoplastic material under the influence of compressed air pressure (Fig. 16, *c*) by the work of compressor.

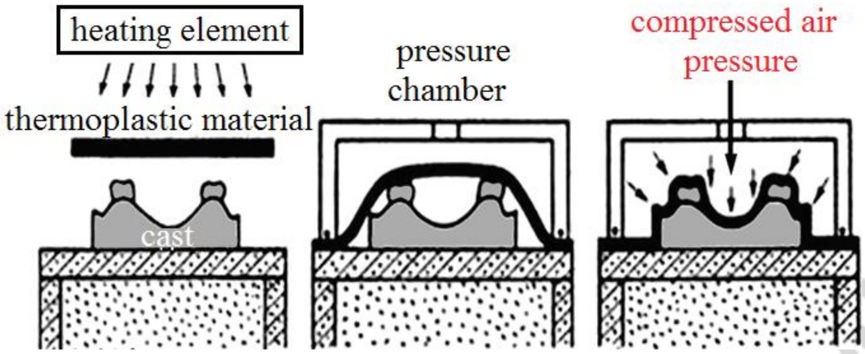


Fig. 16. The scheme of the custom impression tray fabrication with polymer material by pressure thermoforming

The custom impression tray is trimmed around outline after cooling, the edges are smoothed out and the plastic handle is attached with a special glue (Fig. 17).

Fig. 17. Custom impression trays fabricated with polymer material by pressure thermoforming (Dreve Dentamid GmbH, Germany)

Comparing the two technologies of custom impression trays fabrication by thermoforming, it should be noted the advantages of pressure thermoforming, which provides better accuracy of adapting the material, because of significant external pressure of compressed air.

THE CUSTOM IMPRESSION TRAYS FABRICATION BY ADDITIVE MANUFACTURING TECHNOLOGIES

Digital (CAD/CAM) technologies are gaining popularity in modern dental laboratories. Nowadays they also have application for the custom impression trays fabrication.

Digital technology includes three step-by-step operations: data gathering, data processing (CAD, *computer aided design*) and manufacturing process (CAM, *computer aided manufacturing*).

Data gathering is carried out by scanning a gypsum cast made on the basis of an anatomical impression. The custom impression tray is modeled using a special program (CAD technology). The simplicity of modeling includes the following things: the program automatically blocks-out the undercuts, leaves the necessary gap between the tray and the cast, draws the borders of the tray (Fig. 18). At the same time, the dental technician is still able to correct any stage of custom impression tray modeling (Ervandyan A., 2016).

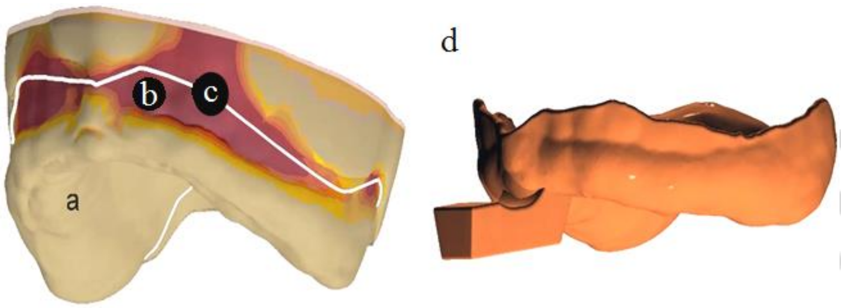


Fig. 18. Computer modeling of the custom impression tray: digital cast (*a*), undercuts (*b*), borders of the tray (*c*) and virtual digital model of the tray (*d*) (screenshot www.youtube.com/watch_time_continue)

After completion of modeling work, the file with the virtual digital model of the custom impression tray is transmitted for automatic manufacturing of the real object (CAM technology). Automatic manufacturing can consist of creating an object by milling (subtractive manufacturing) or by layer-by-layer material addition (additive manufacturing). One of the most widely used methods of additive manufacturing for automatic fabrication of custom impression trays is stereolithography (Stereo Lithography Apparatus, SLA).

3D printing technology is based on layer-by-layer curing of a liquid resin material by laser beam. The basic mechanism of stereolithography 3D printing is shown in fig. 19. A platform is placed in a tank with a liquid resin, on which the prototype will be built. The digital model of a custom tray is divided into layers. Initially, the platform lowers into liquid resin 0.02 mm deep. Then the laser is turned on. The laser beam through the scanning mirror generates a thin cured layer of resin, which corresponds to the first layer of the tray. Afterwards the building platform lowers exactly one layer to a depth of 0.02 mm and the second layer of the digital custom impression tray is polymerized with a laser beam. Repeating this procedure, all the layers of the tray are printed in turn.

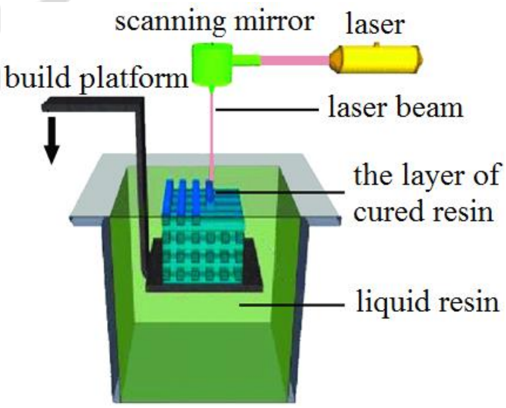


Fig. 19. A graphic scheme of the basic mechanism of stereolithography 3D printing

After building the printed jobs are placed in the bath with a special liquid for complete cleaning from residual material, then in a UV- light curing box for final polymerization. Like many other 3D-printing methods, SLA (stereolithography) requires the building platform that is removed, when 3D printing is finished.

Light-curing materials, that change their properties under the influence of ultraviolet light, are used for the custom impression tray fabrication. Normally the light-curing material is fluid, but it hardens under UV radiation of the electromagnetic range. The duration of light exposure and the wavelength depend on the particular material, size of the object, and environmental conditions. The world leader in the production of light-curing materials is NextDent (the Netherlands), which produces the NextDent ™ Tray. This material is a monomer based on acrylic esters and used for fabrication of 3D-printed custom impression trays (Fig. 20).

Fig. 20. The material for 3D-printing (NextDent ™ Tray, The Netherlands)

NextDent Tray is a class I and CE-certified material for manufacturing of 3D-printed custom impression trays. The material affords to produce high-precision volumetric digital printing at high speed, to create even the most complicated shapes in a few minutes (Fig. 21). Printed forms have sufficient rigidity for further work with any type of impression material.

Fig. 21. 3D-printed custom impression trays

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