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What You Need to Know About Automated Aligner Trimmers

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Automated aligner trimming is the next big improvement for aligner production lines. Moving from hand trimming to machine trimming is a first step into automation for many people. There are pitfalls to be avoided to make sure your investment pays off rather than becoming an expensive science experiment. In this paper, we'll cover the points you should consider before you purchase an automatic aligner trimming solution.

What's wrong with hand trimming?

You are reading this because you already know that trimming aligners by hand is **expensive**, **tedious**, **hand-cramping work.** Business owners must also consider the costs of turnover (hiring, re-training, and learning curve), injuries, floor space, workstation equipment and lost production to name a few. We have found through talking with our customers that there are some other less obvious benefits to automated trimming:

- improved quality, efficiency, and throughput
- scalloped cutting becomes economical
- reduced employee burnout
- ability to scale without raising overhead costs
- reduced scrap and improved safety

The Economics of Automated Trimming

Even at one case per day, automated trimming with Trimlign can save money. Table 1 shows the possible savings with one Trimlign and lower volume production levels. Table 2 shows the possible savings for high volume operations with multiple operators and multiple Trimlign machines.[1] These costs savings do not include the addition of the significant costs mentioned in the previous paragraph.

Table 1: Low Volume Production Savings[1] (1 - 20 cases per day)

Approximate annual savings going from hand trim to 1 Trimlign machine

Number of cases per day	Cut Type 100% Straight	Cut Type 75% Straight 25% Scalloped	Cut Type 50% Straight 50% Scalloped	Cut Type 25% Straight 75% Scalloped	Cut Type 100% Scalloped	Number of Operators
1	$1,984	$3,636	$5,289	$6,942	$8,595	1
3	$5,951	$10,909	$15,867	$20,826	$25,784	1
5	$9,918	$18,182	$26,446	$34,710	$42,973	1
10	$19,835	$36,363	$52,891	$69,419	$85,947	1
15	$29,753	$54,545	$79,337	$104,129	$128,921	1
20	$39,671	$73,942	$108,214	$142,486	$176,758	1

Table 2: High Volume Production Savings[1] (20 - 240 cases per day)

Approximate annual savings going from hand trim to 1 - 15 Trimlign machines

Number Trimlign units	Number cases per day	Number aligners per month	Number aligners per year	Cut Type 100% Straight	Cut Type 75% Straight 25% Scalloped	Cut Type 50% Straight 50% Scalloped	Cut Type 25% Straight 75% Scalloped	Cut Type 100% Scalloped	Number of Operators
1	20	10,440	125,280	$39,671	$73,942	$108,214	$142,486	$176,758	1
2 to 3	40	20,880	250,560	$103,648	$172,193	$240,738	$309,283	$377,829	
3 to 4	60	31,320	375,840	$167,625	$246,135	$348,952	$451,769	$554,587	2
4 to 5	80	41,760	501,120	$207,295	$344,386	$481,476	$618,567	$755,658	
5 to 6	100	52,200	626,400	$271,273	$442,637	$614,001	$785,365	$956,729	
6 to 7	120	62,640	751,680	$335,250	$516,579	$722,214	$927,850	$1,133,487	3
7 to 8	140	73,080	876,960	$374,921	$614,830	$854,739	$1,094,648	$1,334,558	
8 to 10	160	83,520	1,002,240	$438,898	$713,080	$987,263	$1,237,134	$1,511,316	4
9 to 11	180	93,960	1,127,520	$502,875	$787,022	$1,095,477	$1,403,932	$1,712,387	
10 to 12	200	104,400	1,252,800	$542,546	$885,273	$1,228,001	$1,570,729	$1,913,459	
11 to 13	220	114,840	1,378,080	$606,523	$983,524	$1,336,215	$1,713,215	$2,090,216	5
12 to 15	240	125,280	1,503,360	$670,500	$1,057,466	$1,468,739	$1,880,013	$2,291,287	

The colored zones correspond to the number of operators shown on the right side of the table.

1 See appendix A for details of how these savings were measured

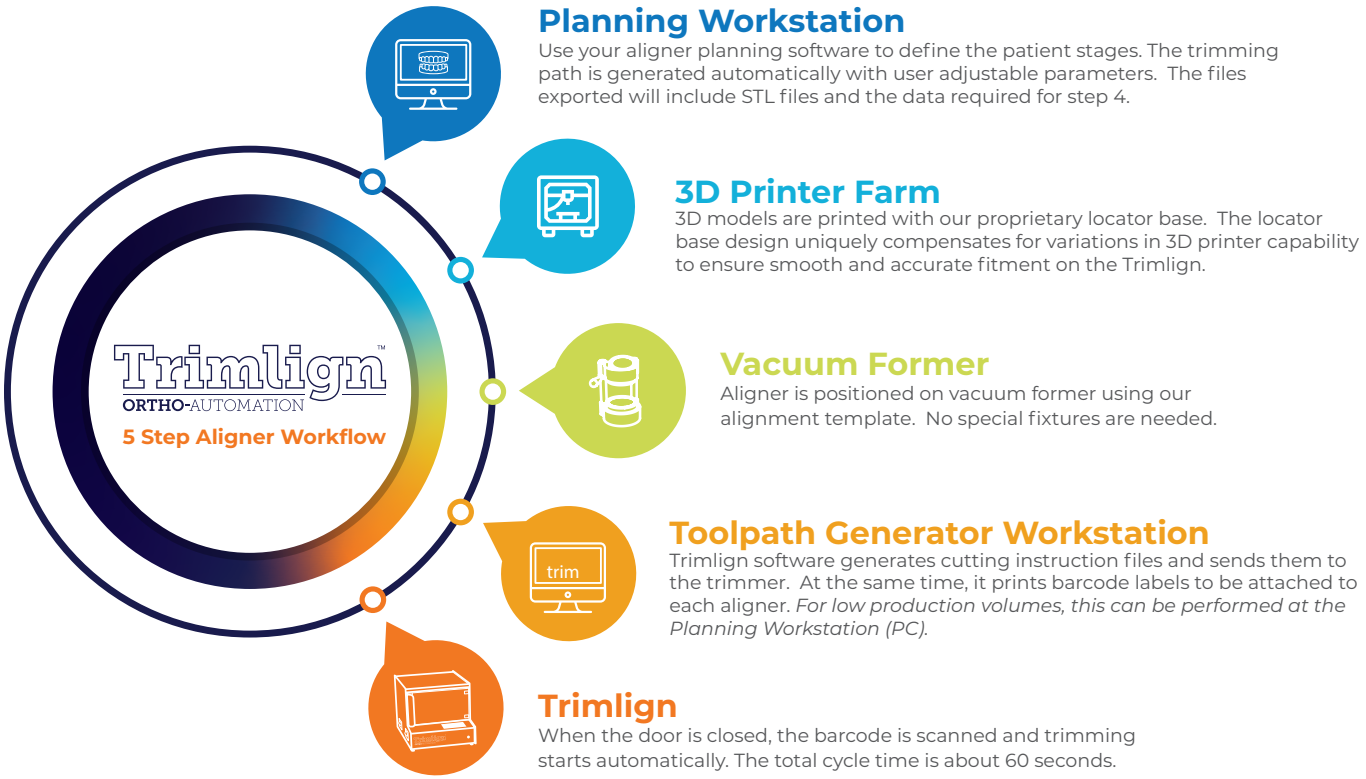
Implementation is everything

When implemented correctly, automated trimming is obviously worth the investment. When introducing any kind of automation on a production line, it is important to dig into the details of how the new equipment interacts with the other production steps to make sure that throughput is increased, and the chances of errors or scrap go down. **Our goal is to be transparent and explain in detail how to integrate automatic trimming into your workflow so these objectives are met.**

Trimlign was developed and tested by engineers with decades of experience in various fields including orthodontic production automation, factory robotics, durability test of aircraft, operations and logistics of mobile phone factories, and development of large CNC fabrication equipment. This background allows the Ortho-Automation team to see trimming operations from multiple angles. Trimlign is much more than a CNC machine. It is a well thought out and fully integrated solution for your aligner production line.

Below is an illustration of the aligner workflow with Trimlign. Most will recognize the basic workflow. The illustration only highlights the changes necessary to integrate Trimlign, and does not include post processing steps such as quality control, cleaning, and packaging that are not impacted. The Trimlign system is designed to allow you to scale your operation from a single operator and Trimlign machine, to a single operator running three Trimlign machines, up to multiple operators running multiple Trimlign machines.

Figure 1, Trimlign "Internal Barcode Mode" Steps

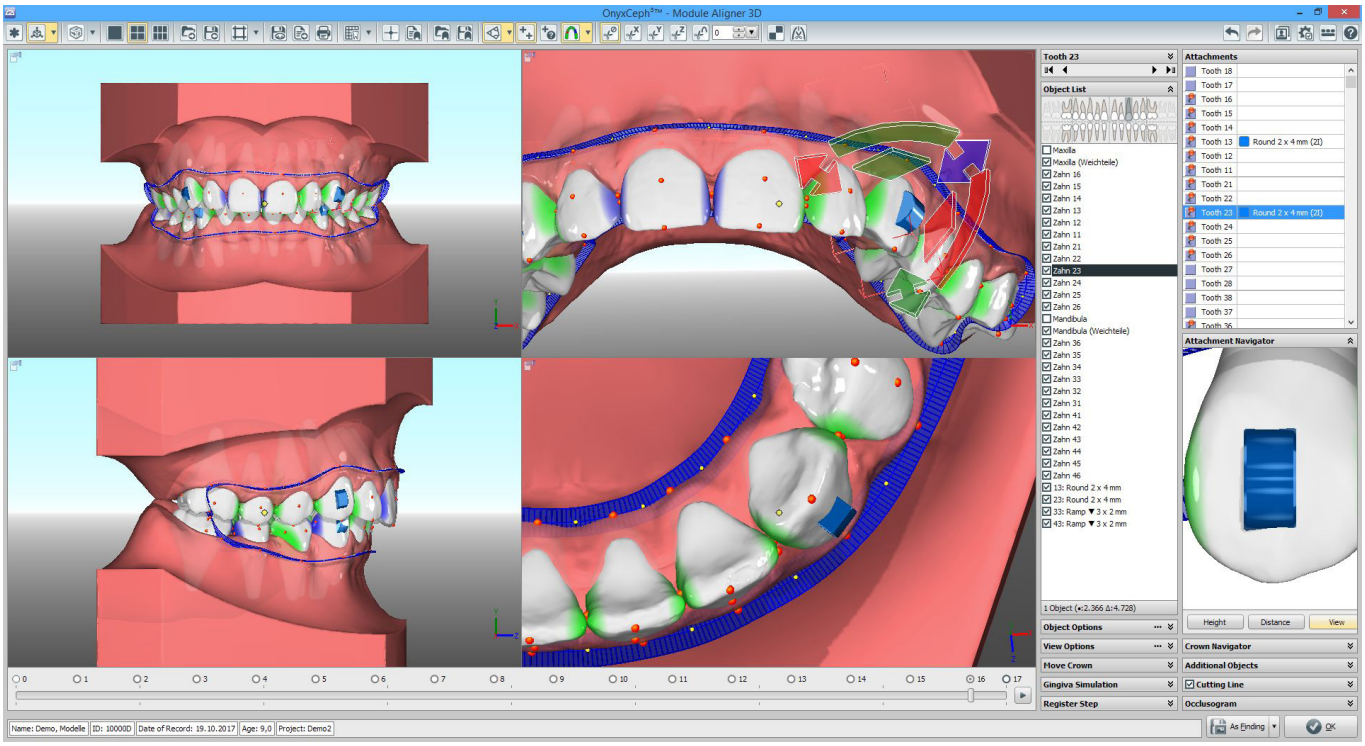


Let’s explore each of these steps in detail.

Step 1 – Aligner Planning Software Workstation

We have worked to integrate Trimlign with most of the major aligner planning software packages. Inside of your treatment planning software, the planning of the trimming path is done as a final step in the treatment planning right before you export the STL models for printing. This process involves adding a fixture base and generating a trimming path for the Trimlign machine. The initial trimming path is automatically calculated as an offset from the gingival margin based on parameters you can configure. When the STL models are exported for 3d printing, our software partners will also export the trimming path in the Trimlign open-protocol format, ready to be processed by the Trimlign Toolpath Generator in step 4.

Figure 2, OnyxCeph3™ automatically calculates the trimming path.



Step 2 – 3D Printing

Affordable 3D printing[2] is what makes in-house aligner production possible. After working with several customers, we’ve learned that it is common for their 3D printer farms to consist of different makes and models of 3D printers. We measured the accuracy of various 3D printers and found that most tend to print under-size. They had varying accuracy, but fortunately usable repeatability. This is very important because the precision locator is usually a 3D printed feature added to or subtracted from the 3D aligner model. Consider a precision locator feature that is printed smaller than intended

2 3D printing will likely include post cure and drying equipment which is not discussed here.

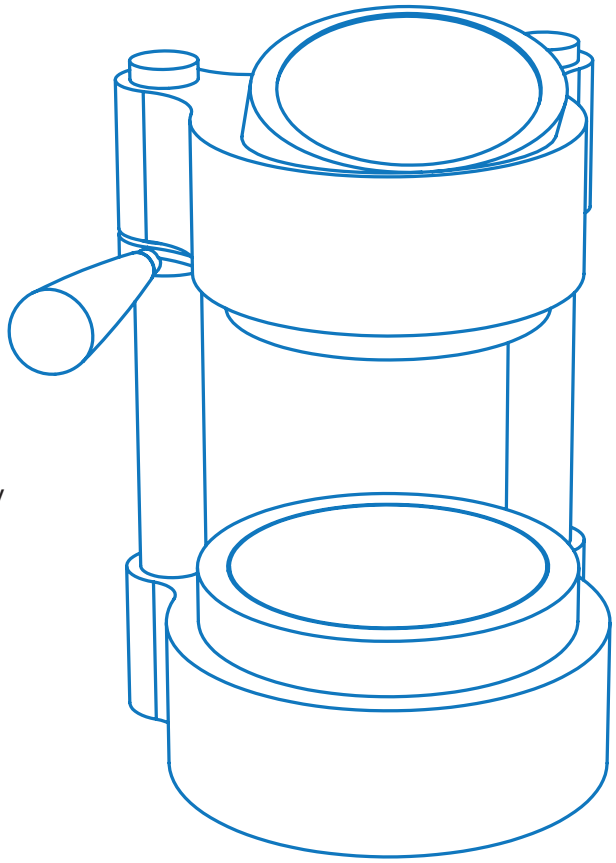
and with varying accuracy depending on the 3D printer that made it. This can cause 3D aligner models to fit to tightly or too loosely, or not at all on the trimmer. If you don't have precise location of the 3D model you can't have consistent trimming or smooth flow of aligners in your production. As far as we know, Trimlign is the only system that solves this variability problem.

After extensive testing with customers like yourself, we have developed the Trimlign Universal Locator System. Our solution allows your aligner planning software provider to offer two Trimlign locator types, one subtractive feature, and the other an additive feature. **The Trimlign locator is unique because it can automatically compensate for 3D printer variations.** Each of the two locator types is available in three different sizes so you can choose the one that works best with your 3D print farm. The result from testing with two independent sources has been each aligner fits smoothly and accurately on the Trimlign.

When considering any automated trimmer solution, it is critical to consider how the trimming path is generated, and the precision locator system used to position the aligner on the trimmer. Either of these steps has the potential to cause problems on your production line and reduce the benefits of automation. Step 5 discusses this precision locator system from a cycle time point of view.

Step 3 – Vacuum Forming

The trimming step separates the vacuum formed plastic into two sections, the aligner, and the waste. The waste portion of the plastic surrounds the 3D printed aligner, which means it can potentially interfere with the trimmer's moving parts. Collisions can result in scrapped parts or damage to a trimmer. For this reason all automatic trimmers require the user to precisely position the 3d model on the vacuum former platen.



When considering an automated trimmer, consider how it impacts your existing vacuum form equipment. Do you need to buy compatible vacuum formers or modify your existing equipment? Can you tolerate the expense or down time?

Step 4- Generating Toolpaths and Transferring Data

A stand-alone PC is used to process the data files provided by the aligner planning software to create cutting instructions for the trimmer. The Trimlign is unique because it offers three different production modes to allow you to gracefully scale from a small operation with a single worker, to a large production line with multiple workers running multiple Trimlign machines.

- **Single Mode** – **For lower volume operations being run by a single operator**, the toolpath generator program will send the generated cutting instructions to the Trimlign through the network, and the Trimlign will prompt the user to load this specific aligner. When cutting for that aligner is completed, the PC program will allow the next aligner to be selected. If you don't yet have the high production volume required to keep the Trimlign busy, this is an efficient mode in which to run the machine.

- **Continuous Mode with Internal Scanner** – For high volume operations with multiple workers, a different approach is used to prevent a bottleneck at the Trimlign machine. After the vacuum form station, one or more operators will run the toolpath generator software on a PC , which creates labels that are applied to the vacuum form disc. During this process, the toolpath generator will also send the generated cutting files to the Trimlign via the network. This allows Trimlign operators to keep the machines running full time without worrying about data entry. The operator only needs to load the aligner and close the door. When the door is closed, Trimlign will begin searching for a barcode on the aligner, look up the file, and begin trimming. **This is the fastest mode and achieves the highest hourly throughput.** Operating a Trimlign is so easy, you can hire unskilled laborers for this job. Since one operator can manage up to three Trimligns, you can save even more. This high-volume strategy allows you to get the most out of your investment.

- **Continuous Mode with External Scanner** – This is like the continuous mode above, except that it allows the Trimlign owner to use their own scanner to identify which aligner is being loaded into the Trimlign. **Trimlign will accept input from any HID device on its external USB port.** We have provided this mode to allow users the flexibility to add additional automation around the Trimlign machine.

When evaluating any aligner trimming machine, be sure to consider how the data is loaded into the machine, how long it takes, and the potential for human error, and how your operation will scale with the solution being offered.

Step 5 – Automated Trimming

Now for the trimming machine itself. **This is where the purposeful design of Trimlign separates it from the competition.**

Safety

Trimlign has several safety features that warrant explanation. The shatter and scratch resistant polycarbonate door keeps debris inside the machine. The door uses two redundant hall effect sensors to monitor door opening and closing. An electric solenoid locks the door at appropriate times to keep the operator from inadvertently interrupting Trimlign. The cutter used to trim aligners is very sharp and the Trimlign parks the cutter in the cutter shield during the load/unload step. A cutter depth gauge provided with the Trimlign tool kit is used to set the cutter depth but also to keep sharp edges away from the operator. When the Trimlign computer senses the cutter is parked in the shield or the door is unlocked, the power to the spindle motor is shut off so the spindle cannot turn on. A switch in the cutter shield is used during some functions to detect the cutter and to verify the cutter length to ensure consistent operations. The Trimlign uses four axes of motion to drive the cutter around the trim path. Each axis uses a sensor to track its position. If the Trimlign door is forced open, all motion halts and power is removed from the spindle. The spindle will then stop spinning within a few seconds. These features along with the steel and aluminum enclosure, result in a machine that is very safe to operate. **To provide a safe environment for your employees, it is important to investigate and understand trimmer safety features on any machine you consider.**

Cycle Time

The Trimlign locator system used on the 3D aligner models requires only seconds for loading and unloading. There are no screws or special fixtures required to adapt the 3D aligner model to the trimmer. Locating pins on the Trimlign engage the 3D aligner model locator features and an automatically activated high volume vacuum system holds the 3D aligner firmly in seconds. A vacuum sensor onboard the Trimlign is monitored to ensure there are no vacuum leaks and the operator will be notified if the aligner was improperly loaded. Pay close attention to how the trimmer you select holds down the 3D aligner model during trimming. Some machines require screws or other cumbersome fixturing for each aligner. **It is important to understand the entire workflow to avoid unnecessary steps which waste valuable production time.**

Lab Space

When in the continuous modes, a barcode is read to ensure the proper trim data file is loaded. The data files are generated by a central PC for any number of Trimligns. A separate PC is not required for each trimmer, which reduces your overall cost and counter space. **Be sure to inquire if the automated trimmer you are considering requires a dedicated PC to operate.**

Debris Collection

The same automatic high-volume vacuum that secures the 3D aligner model during trimming is used to extract and capture the cut debris. Trimming aligners with a cutter generates tiny pieces of plastic which are much larger than dust, so they are not airborne particles. Our vacuum system automatically captures most of this plastic. The high-volume vacuum system uses a catch bag and air filter. The catch bag can be cleaned and re-used or replaced. The filter will likely last a very long time since the Trimlign doesn't generate dust particles. For comparison, a laser trimming system creates toxic fumes that must be vented outside, and in some municipalities, captured in a specialized filter system. All machines will generate waste in the form of debris or fumes. **When evaluating different trimmers, consider if the machine manages the waste and what modifications are required to be made to your facility.**

Lab Resources Required

Trimlign and its high volume vacuum are a self-contained system. You only need to connect each Trimlign to your local network, **no cloud-based services are required. The Trimlign does not need an external compressed air or vacuum supply.** The entire system runs on 115V/15A (USA) or 230/7.5A (EU) circuit found in any lab.

Construction

Trimlign is a solid machine manufactured to high quality standards. The Trimlign is a 4-axis machine having a turntable that rotates and three linear motion axis X, Y and Z. Some trimmers use 5 axes of movement for the task of trimming aligners, when in reality, only 4 are required. If you watch a 5-axis machine cutting an aligner, you will notice the cutter angle relative to the gingiva is very consistent. This is because the spindle motor and cutter can only approach the gingiva from a very narrow window or risk a collision. Some manufactures even want to charge the customer for collision avoidance software! It is impossible to keep the cutter perpendicular to the gingiva and this is not necessary. Consider that the aligner is very thin, so the exact angle of the aligner edge is imperceptible to the patient. We believe that designs that use 5 axes for this task result in a machine that is less reliable, more expensive to repair, larger, and time consuming to calibrate. **In this case, more is not better.** To illustrate this, let's consider trimmer calibration.

Calibration

One often overlooked aspect of an automated trimmer is calibration, the process of identifying and correcting for small variances in the trimmer to provide precision motion. **The Trimlign is a compact 4-axis machine where each axis is solidly attached to the Trimlign cast aluminum plates.** This means the axis alignment relative to each other is very stable. The mechanics of a 5-axis machine

provide motion flexibility sometimes at the detriment of stability. As we have stated, the extra flexibility is not used when trimming aligners, which means you sacrifice stability for no gain. A Trimlign machine is so stable calibration is rarely needed except after shipping, or maintenance.

The Trimlign calibration process is fully automated. The operator selects "calibrate" from the touch screen menu and follows the prompts and pictures to insert the calibration fixture. The Trimlign executes pre-programmed moves and self-calibrates in about 4 minutes. Some 5-axis machines require the operator to setup and read dial gauges while mechanically adjusting each axis by trial-and- error. Calibrating a 5-axis system should be done by a qualified or trained operator. More fragile 5-axis designs may need calibration on a routine basis because they get out of adjustment. If mistakes are made during the calibration, or the machine gets out of calibration, the processed aligners will likely be scrap. T**o avoid surprises, be sure to inquire about the detailed calibration method used on the trimmers that interest you.**

Summary of Trimlign Features

Designed specifically for aligner production. Optimized to make trimming operations easy and less expensive.

Low cost of ownership and easy to maintain. Maintenance requirements are managed by the onboard computer. The touch screen guides the user through operations and maintenance.

Safety and reliability are designed in to protect your employees. Features a locking door, redundant safety sensors, and a cutter shield.
No hazardous laser fumes.

Small footprint.
22"D x 17.5"W x 17.5H"
Weight 75 lbs. Stackable with optional bracket kit.
No dedicated PC, compressed air, vacuum supply, or internet connection required.

Automatic management of aligner data eliminates errors. Trimlign operator just places aligners for trim.

Trimmed edges rarely need buffing. Results can vary by material. We can optimize cut parameters for your materials.

Straight or scalloped cuts are possible as well as elastics cutouts or other special features.

Easy to use. Loading and unloading aligners takes only seconds thanks to the automatic vacuum hold down.

Automatic calibration. Follow the touch screen prompts to install the calibration tool, then press the calibrate button. The rest is done by the time you come back from a coffee break.

Completely integrated solution with aligner planning SW, 3D printers, vacuum formers & trim path data management.

Trim up to 480 aligners in 8 hours with 1 Trimlign. **Trim up to 1440 aligners** in 8 hours with one operator and 3 Trimligns.

No hidden fees! No charges per aligner. No extra software to buy. All firmware and software for the trimmer are included.

Automatic debris extraction. Automatically controls a quiet debris capture system, which can also be used to clean the aligner trim station.

Integrated QR scanner to enable rapid cycle times.
External scanners are also supported to enable customizing your workflow.

Automatic cutter compensation. When a cutter is changed, Trimlign measures cutter length and corrects for variance.

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Conclusions

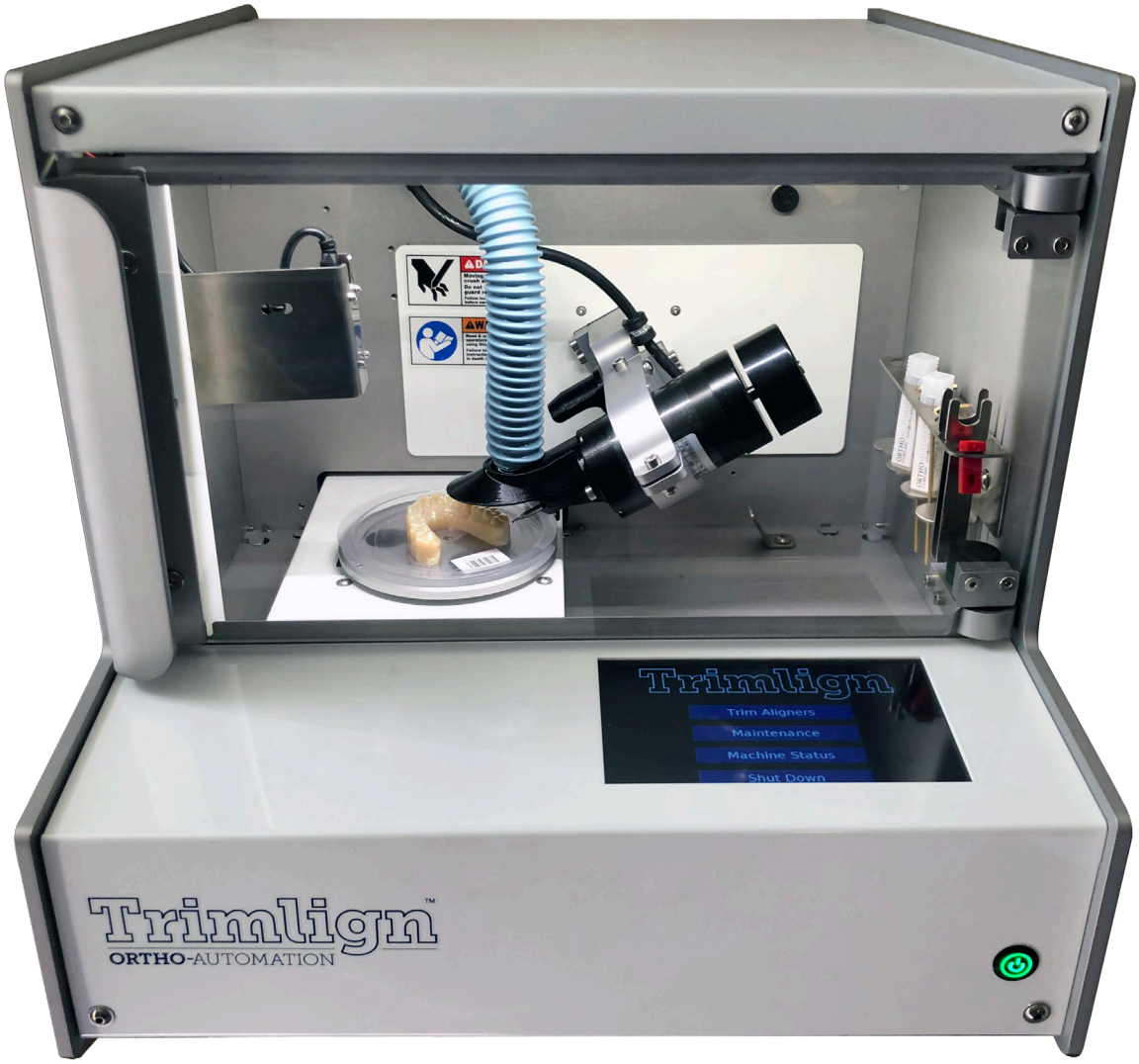
We hope you've found this paper a useful resource. Adding an automated trimmer to your operations is well worth the investment. Just be sure to understand what is needed so the integration will be easy and cost effective. **Here is a summary of items to consider when buying an automated trimmer.**

1. **Know why you are adding an automated trimmer.** Here are some very good reasons.
    a. Lower the cost of operations.
    b. Safer than hand trimming with less stress on employees.
    c. Increase capacity or scale with minimal costs.
    d. Improved quality and less scrap.
    e. Offer scalloped aligners at an economic price.
    f. Give my team the best tools.
    g. Reputation of having a high-tech operation.
2. **Know the impacts to your facility.**
    a. Is the trimmer designed to be safe? Does it have a locking safety enclosure? What will my insurance provider think?
    b. Must I add a PC for each trimmer?
    c. How much floor space is required?
    d. Does debris or fume extraction/collection need to be added?
    e. Will the prints from the 3D print farm work with the aligner locator system?
    f. Are changes required to the vacuum form machines?
    g. Does the trimmer need compressed air or vacuum systems?
    h. Does the trimmer need network connection or internet connection?
3. **Know the impacts to personnel.**
    a. Can my team learn and manage the software?
    b. What labor skills are required for the new workflow?
    c. Does the automated trimmer require skilled labor for calibration and maintenance?
    d. Can my team be trained to use the new equipment?
    e. Does the new workflow require lower or higher paid employees?
4. **Know the impacts to workflow.**
    a. Is the new workflow prone to human error or help reduce it?
    b. Do I understand the trimmer well enough to know the true hourly capacity of the trimmer?
    c. What is the load and unload method and associated time?
    d. Does the trimmer require special fixtures to mount the 3D aligner model? If yes, what is the cost and impact to time?
    e. What part of the workflow limits the output?
    f. Can I scale the new workflow?
    g. What needs to be added when I scale the workflow?
    h. If the trimmer processes multiple aligners at once, understand how the batch processing impacts your workflow.

5. **Know the costs.**
    a. If I do need more equipment, what does it cost and where will it fit in my facility?
    b. What costs are associated with the trim path data and locator base functions of the aligner planning software?
    c. What costs are associated with the trimmer, both initial investment and any recurring fees such as costs for trim path data conversion to machine code.
    d. Is the trimmer software included in the purchase price and is there an annual renewal fee?

How can we help?

If you are interested in ordering a Trimlign machine, or just have more questions, please contact us at **sales@ortho-automation.com** or call us at **214-856-0642**.



Appendix A. - Savings Analysis Details

The cost analysis of hand trimming and Trimlign was done based on data collected from trials at an orthodontist's lab. The staff at the practice processed several cases both by hand and by Trimlign. The trimming cycle times included the time from when the operator loaded an aligner until the operator unloaded the trimmed aligner. *(Note that some manufacturers only show you the time the blade is cutting, which is misleading)*. To understand the true throughput of an automated machine, the cycle time is the time it takes to load the first aligner, trim and then remove it. Our cost estimator considers the electricity consumed by a hand trim workstation and the Trimlign. Because trimming aligner by hand causes fatigue, this is a much less efficient process than loading and unloading a machine. An efficiency of 70% for hand trimming and 90% for machine loading and unloading was used. The total cycle time for hand trimmed was 150 seconds for straight and 471 seconds for scalloped cuts. The cycle time for Trimlign was 60 seconds for straight and 72 seconds for scalloped cuts. These cycle times include the fore-mentioned efficiencies. The analysis includes a hand scissor cost of $21 with a life of 40 days, and $32 for Trimlign cutters with a conservative life of 3 days. The most important consideration of the calculation is employee pay. The Trimlign has been designed to be simple to operate and doesn't require skilled labor. In fact, we believe operating the Trimlign is as easy as operating a bank cash machine. The unskilled labor pay was 16.7% lower than the skilled labor pay in the analysis. The analysis assumes 24 aligners per patient case. The 8-hour capacity of one hand trimmer is 8 cases for straight cut and 2.7 cases for scalloped cut. The 8-hour capacity for a Trimlign is 20 cases for straight cut and 16.7 cases for scalloped cut. The cut time and hence capacity is very dependent on the size of the jaw and the shape of the cut path. Since aligners are trimmed with straight and scalloped cut paths, the savings analysis provides data for different combinations of both. You will realize more cost savings as more Trimlign trimmers are added to production. This is because the time to load/unload is about 10 seconds including the 90% efficiency while the trim time is about 50 seconds. This means the operator is waiting for 50 seconds during the trim and can manage to load/unload two additional Trimlign machines. Operating three Trimligns with one person essentially divides the trim cost by about three. Therefore, you see big cost benefits when operating three Trimlign machines with one employee. The cost saving data is just an estimate based on a real-world testing, and your savings will likely be different because there are a multitude of variables in aligner production.

Lastly, any additional costs associated with your aligner planning software provider are not included in this analysis. We are not aware of the cost models used by your provider and these cost models will likely evolve as more customers add automated trimming. We also do not include several cost savings that are likely to occur when switching from hand trimming to automated trimming because these are a function of your business. You should add any additional costs and savings when analyzing the impact to your financial operations.